AWARD/CONTRACT

1. THIS CONTRACT IS A RATED ORDER UNDER DPAS (15 CFR 700)

RATING

2. CONTRACT (*Proc. Inst. Ident.*) NO. EP-C-17-031/68HERC20F0051

3. EFFECTIVE DATE See Block 20C

4. REQUISITION/PURCHASE REQUEST/PROJECT NO. PR-OW-19-00566

5. ISSUED BY CODE CAD

CAD
US Environmental Protection Agency
26 West Martin Luther King Drive
Mail Code: W136
Cincinnati OH 45268-0001

6. ADMINISTERED BY (*If other than Item 5*) CODE

7. NAME AND ADDRESS OF CONTRACTOR (*No., street, country, State and ZIP Code*)

TETRA TECH, INC.
Attn: John Hochheimer
10306 EATON PL STE 340
FAIRFAX VA 22030

CODE 198549560

FACILITY CODE

8. DELIVERY

☐ FOB ORIGIN ☒ OTHER (*See below*)

9. DISCOUNT FOR PROMPT PAYMENT

10. SUBMIT INVOICES (4 copies unless otherwise specified) TO THE ADDRESS SHOWN IN

ITEM

11. SHIP TO/MARK FOR CODE CAD

CAD
US Environmental Protection Agency
26 West Martin Luther King Drive
Mail Code: W136
Cincinnati OH 45268-0001

12. PAYMENT WILL BE MADE BY CODE RTP FMC

RTP Finance Center
US Environmental Protection Agency
RTP-Finance Center (AA216-01)
109 TW Alexander Drive
www2.epa.gov/financial/contracts
Durham NC 27711

13. AUTHORITY FOR USING OTHER THAN FULL AND OPEN COMPETITION:

☐ 10 U.S.C. 2304 (c) ( ) ☒ 41 U.S.C. 3304 (a) ( )

14. ACCOUNTING AND APPROPRIATION DATA

See Schedule

15A. ITEM NO	15B. SUPPLIES/SERVICES	15C. QUANTITY	15D. UNIT	15E. UNIT PRICE	15F. AMOUNT
	Continued				

15G. TOTAL AMOUNT OF CONTRACT $119,652.23

16. TABLE OF CONTENTS

(X)	SEC.	DESCRIPTION	PAGE(S)	(X)	SEC.	DESCRIPTION	PAGE(S)
		PART I - THE SCHEDULE				PART II - CONTRACT CLAUSES	
	A	SOLICITATION/CONTRACT FORM			I	CONTRACT CLAUSES	
	B	SUPPLIES OR SERVICES AND PRICES/COSTS				PART III - LIST OF DOCUMENTS, EXHIBITS AND OTHER ATTACH.	
	C	DESCRIPTION/SPECS./WORK STATEMENT			J	LIST OF ATTACHMENTS	
	D	PACKAGING AND MARKING				PART IV - REPRESENTATIONS AND INSTRUCTIONS	
	E	INSPECTION AND ACCEPTANCE			K	REPRESENTATIONS, CERTIFICATIONS AND OTHER STATEMENTS OF OFFERORS	
	F	DELIVERIES OR PERFORMANCE					
	G	CONTRACT ADMINISTRATION DATA			L	INSTRS., CONDS., AND NOTICES TO OFFERORS	
	H	SPECIAL CONTRACT REQUIREMENTS			M	EVALUATION FACTORS FOR AWARD	

CONTRACTING OFFICER WILL COMPLETE ITEM 17 (SEALED-BID OR NEGOTIATED PROCUREMENT) OR 18 (SEALED-BID PROCUREMENT) AS APPLICABLE

17. ☒ CONTRACTOR'S NEGOTIATED AGREEMENT (*Contractor is required to sign this document and return ______ copies to issuing office.*) Contractor agrees to furnish and deliver all items or perform all the services set forth or otherwise identified above and on any continuation sheets for the consideration stated herein. The rights and obligations of the parties to this contract shall be subject to and governed by the following documents: (a) this award/contract, (b) the solicitation, if any, and (c) such provisions, representations, certifications, and specifications, as are attached or incorporated by reference herein. (*Attachments are listed herein.*)

18. ☐ SEALED-BID AWARD (*Contractor is not required to sign this document.*) Your bid on Solicitation Number 68HERC19R0081, including the additions or changes made by you which additions or changes are set forth in full above, is hereby accepted as to the items listed above and on any continuation sheets. This award consummates the contract which consists of the following documents: (a) the Government's solicitation and your bid, and (b) this award/contract. No further contractual document is necessary. (Block 18 should be checked only when awarding a sealed-bid contract.)

19A. NAME AND TITLE OF SIGNER (*Type or print*)

20A. NAME OF CONTRACTING OFFICER Andrea Dehne

19B. NAME OF CONTRACTOR

BY ______________________
(*Signature of person authorized to sign*)

19C. DATE SIGNED

20B. UNITED STATES OF AMERICA

BY Andrea C. Dehne ELECTRONIC SIGNATURE
(*Signature of the Contracting Officer*)

20C. DATE SIGNED 11/14/2019

AUTHORIZED FOR LOCAL REPRODUCTION
Previous edition is NOT usable

STANDARD FORM 26 (Rev. 3/2013)
Prescribed by GSA - FAR (48 CFR) 53.214(a)

NAME OF OFFEROR OR CONTRACTOR
TETRA TECH, INC.

ITEM NO. (A)	SUPPLIES/SERVICES (B)	QUANTITY (C)	UNIT (D)	UNIT PRICE (E)	AMOUNT (F)
	DUNS Number: 198549560 TOCOR: Susan Jackson Max Expire Date: 11/13/2020 Delivery: 11/13/2020 Period of Performance: 11/15/2019 to 11/13/2020 Fully Funded Firm Fixed Price Task Order				
0001	Task Order Issuance Line Item: Technical Support for EPA/ORD Ecological Assessment Programs Accounting Info: 19-20-B-28H-000BD4X20-2505-1928CHH033-001 BFY: 19 EFY: 20 Fund: B Budget Org: 28H Program (PRC): 000BD4X20 Budget (BOC): 2505 DCN - Line ID: 1928CHH033-001 Funding Flag: Complete Funded: $115,009.04 Accounting Info: 20-21-B-28H-000BD4X20-2505-1928CHH033-002 BFY: 20 EFY: 21 Fund: B Budget Org: 28H Program (PRC): 000BD4X20 Budget (BOC): 2505 DCN - Line ID: 1928CHH033-002 Funding Flag: Complete Funded: $4,643.19 Delivery-Invoice Payment Schedule shall not exceed a frequency greater than once a month and 90% of the task order price. Acceptance for invoicing is based on deliverable approval by the TOCOR. For efficient processing IAW FAR clause 52.232-32, performance based payment invoicing amounts will not be submitted until the TOCOR provides deliverable approval. The TOCOR will notify Tetra Tech within 14 days of submission of a deliverable of EPAs intention to approve or disapprove. TOCOR: Susan Jackson/(202)566-1112/jackson.susank@epa.gov ALTOCOR: Janice Alers-Garcia/(202)566-0756/alers-garcia.janice@epa.gov				119,652.23

PERFORMANCE WORK STATEMENT PR-OW-19-00566
Contract #EP-C-17-031
TASK ORDER 68HERC20F0051/SOL#68HERC19R0081

I. Title: Development of Biological Indicators and Criteria, Methods and Assessment Integration

II. Period of Performance: November 15, 2019 to November 13, 2020

III. Task Order Contracting Officer Representative (TOCOR):

Susan Jackson
Health and Ecological Criteria Division
Office of Water, Office of Science and Technology
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue (4304T)
Washington, DC 20460
Tel: (202)566-1112, Fax: (202)566-1140
jackson.susank@epa.gov

Alternate TOCOR:

Janice Alers-Garcia
Tel: (202) 566-0756, Fax: (202)566-1140
alers-Garcia.janice@epa.gov

IV. Background Information:

The Clean Water Act (CWA) directs EPA to restore and maintain the biological integrity of the Nation's waters. Under the CWA, the EPA has established a Water Quality Standards (WQS) Program to help achieve this objective. Biological criteria, developed using biological assessments and other ecological assessment data, are a component of a WQS and can be used to support overall water quality management (WQM) program information needs. The EPA is developing methods and tools to support incorporation of biological and other ecological assessment data into EPA, state, territorial, tribal and county (herein defined as "state") WQM programs, including developing, evaluating and implementing assessment approaches using biological, chemical and physical data; developing and testing user friendly databases; query, data visualization and database management approaches and tools; reviewing and synthesizing of existing data, methods and literature to efficiently build on an established body of scientific research and practice; and evaluating the statistical robustness of technical methods and approaches for assessments and model prediction. To develop effective methods and support for states, communication and engagement is fundamental in the planning, development and transfer of results.

If needed for purposes of technical clarification, use of technical collaboration will be in writing and sent to the Contracting Officer and the Task Order Contract-Level COR.

V. Objectives

This task order (TO) is to support the development of a Biological Condition Gradient (BCG) for Streams and Wadeable Rivers in the Pacific Northwest Maritime Region (See Task 2); finalize the numeric BCG framework and decision rules for coral reef ecosystems using benthic and fish assemblage data and information (See Task 3); and provide technical support to states through informal technical consultations (See Task 4).

VI. Quality Assurance (Contract PWS Section 5)

The contractor shall address the QA requirements of this TO through a combination of the following: 1) Tetra Tech SOP for Statistical Analyses (Appendix A, March 2017), 2) Tetra Tech SOP for Secondary Data Management (Appendix B, March 2017), and 3) Tetra Tech SOP for Geospatial and Data Management (Appendix C, March 2017) which document how quality assurance and quality control will be applied to the collection and use of existing environmental data and/or survey information for this TO. The contractor shall discuss with the TOCOR if any of the specific TO tasks are not readily covered under the approved SOPs. If not readily covered under the approved SOPs then a supplement QAPP shall be developed if needed.

Any project specific quality assurance issues shall be reported in the monthly progress reports as specified under Subtask 1. The contractor shall document relevant QA activities in any deliverable. All QA documentation prepared under the TO shall be considered non-proprietary. The contractor shall provide a signed review sheet (in the front of the SOPs/QAPPs) indicating the SOPs/QAPPs have been read and shall be followed by all personnel participating in this TO.

The contractor shall submit relevant QA documentation as requested by the TOCOR. The contractor shall permit a QA review of data entry documents and procedures by an authorized agent of EPA at any time during the performance period (given advanced notification).

Task 2 Develop Biological Condition Gradient (BCG) for Streams and Wadeable Rivers in the Pacific Northwest Maritime Region and Task 3 Develop numeric BCG framework and decision rules for coral reef ecosystems using benthic macroinvertebrate communities and fish assemblage data and information support development of a first-generation numeric model. The contractor shall fulfill the requirements described in National Risk Management Research Laboratory (NRMRL) QAPP Requirements for Research Model Development and Application Projects (10/2008) for applicable areas of Task 2 and 3. The NRMRL QAPP requirements are included in Appendix D of this TO.

<u>Information Quality Guidelines & Information Quality Review</u>

The contractor shall ensure the products developed under this TO comply with EPA's Quality System and other related QA policies, and the Office of Water's Quality Management Plan. The contractor shall ensure that the information in the products meets the standards of "Objectivity", "Integrity", "Utility", "Reproducibility" and "Transparency" as described in the OW Information Quality Guideline (IQG) for each deliverable from this TO as they may be used in Agency decision-making and/or will be publicly available documents. If requested by the TOCOR via written technical collaboration, the contractor shall provide a memorandum describing how the planned product(s) developed meet EPA's & OW's Information Quality Guidelines. As part of that memo, the contractor shall document the quality assurance procedures used in developing the deliverables under this TO. The contractor shall provide the memo at the time it delivers the Final

Summary Report. As directed by the TOCOR via written technical collaboration, the contractor shall meet with the TOCOR (through teleconference) to discuss the Guidelines and the contractor's role in completing the memo and OW IQG checklist.

VII. Scope of Work

Task 1: Communication, Prepare Monthly Progress and Financial Reports, Coordination and Notification

SubTask 1.1: Communication/Kickoff Call
The Contractor shall contact the EPA TOCOR and schedule a kickoff project meeting.

SubTask 1.2: Communication and development of a regular reporting schedule
The Contractor shall establish communication with the EPA TOCOR and develop a regular reporting schedule throughout the period of the TO.

SubTask 1.3: Monthly Progress and Financial Reports
Submit and prepare monthly progress and financial reports in accordance. The monthly progress report shall include project status, expenditures to date, unexpected problems or concerns, corrective actions, lessons learned, QA/QC activities, and next steps.

SubTask 1.4: Coordination and notification
This task requires coordination with other organizations and therefore it is particularly important that the Contractor shall notify the EPA TOCOR of issues, problems, questions, or delays as soon as they become apparent or if they are anticipated.

Task 1. Deliverables

Task	SubTasks	Deliverable	Due
1	1.1	Communication/Kick-off call	Within 3 days of TO Award
1	1.2	Regular reporting schedule	As requested by the TOCOR
1	1.3	Progress and financial reports	Monthly
1	1.4	Coordination and notifications	Immediately upon knowledge of incident

Task 2: Develop Biological Condition Gradient (BCG) for Streams and Wadeable Rivers in the Pacific Northwest Maritime Region (Contract PWS Section 2, Task Areas 2, 3, 4, 5, 6, 7)

The contractor shall provide technical support to calibrate the BCG for streams in the Pacific Northwest Maritime Region (CONUS). The contractor shall use existing data sets that have documented QA/QC review including but not limited to: Washington and Oregon state biological monitoring datasets (publicly accessible), EPA's StreamCat data (Hill et al. 2016), Indices of Catchment and Watershed Integrity (ICI and IWI, respectively) (USEPA website, publicly accessible) and NorWeST Summer Stream Temperature Model data (Isaak et al. 2017).

SubTask 2.1: Develop a Taxa Tolerance Database for the Maritime Pacific region

2.1.a. Conduct tolerance analyses using the IWI scores, the NorWeST summer stream temperature metrics and up to four StreamCat variables (such as percent urban and percent agricultural land use).

2.1.b. Format analysis results as a taxa tolerance database in a MS Access database.

2.1.c. Document scientific basis and process to clearly illustrate how the results were derived and the ecological basis for this results.

SubTask 2.2: Develop BCG taxa attribute assignments based on taxa tolerance database (upon finalization of SubTask 2.1)

2.2.a. Assign attribute categories to the taxa listed in the data sets used to develop the taxa tolerance database.

2.2.b. Facilitate a webinar with the data providers and state and county bioassessment program scientists to explain the BCG attribute assignments and to solicit their feedback.

2.2.c. Revise attribute assignments based on comments from data providers and state and country bioassessment program scientists.

SubTask 2.3: Develop site assignment worksheets and supporting technical material for BCG development webinar using procedure defined in "A Practitioner's Guide to the Biological Condition Gradient: A Framework to Describe Incremental Change in Aquatic Ecosystems" (EPA-842-R-16-001)

SubTask 2.4: Develop Numeric BCG for streams in the Pacific Northwest Maritime Region

2.4.a. Facilitate 2 to 3 webinars with data providers, state and county bioassessment program scientists and 2 – 3 expert taxonomists using the site assignment worksheets (subtask 2.3)). The objective of the webinars is to develop decision rules for assigning sites to BCG levels using procedure defined in "*A Practitioner's Guide to the Biological Condition Gradient: A Framework to Describe Incremental Change in Aquatic Ecosystems" (EPA-842-R-16-001).*

2.4.b. Based on outcome of webinars, develop numeric BCG for streams in Pacific Northwest Maritime Region (CONUS).

2.4.c. Prepare technical report that documents method, rationale and process for development of numeric BCGs for fish and benthic macroinvertebrates in the Caribbean and for the screening method.

2.4.d. Revise technical report per comments received from TOCOR.

Task 2. Deliverables

Task	SubTask	Deliverable	Due
2	2.1.a-c.	Taxa Tolerance Database	Two weeks after receiving final comments from the TOCOR
2	2.2. a-c	BCG taxa assignments	Two weeks after receiving final comments from the TOCOR
2	2.3	Site Assignment Worksheets	Two weeks after receiving final comments from the TOCOR
2	2.4.a-d	Numeric BCG and Technical Report	Two weeks after receiving final comments from the TOCOR

Task 3: Develop numeric BCG framework and decision rules for coral reef ecosystems using benthic macroinvertebrate communities and fish assemblage data and information. (Contract PWS Section 2, Task Areas 2, 3, 4, 5, 6, 7).

The contractor shall provide technical support to develop numeric BCG models for assigning individual sample sites to biological condition levels for coral reef fish and benthic macroinvertebrate communities in the Caribbean. The contractor shall use existing data sets with QA/QC documentation from the United States Virgin Islands (USVI) and Puerto Rico (PR) territorial monitoring programs and from the National Oceanographic and Atmospheric Administration (NOAA) Coral Reef Monitoring and Marine Sanctuary Programs. The US EPA TOCOR will coordinate with the contractor to ensure that the correct datasets with documented QA/QC review are accessed. An expert panel met in March 2019, to review a model prototype and provide expert comments and recommendations on the prototype. The US EPA TOCOR will provide to the contractor the prototype, summary of the meeting, key findings and recommendations.

SubTask 3.1*: *Develop final numeric BCG for coral reef fish community in the Caribbean

3.1.a. Revise prototype fish model to address expert comments and recommendations.

3.1.b. Using data from USVI, PR and NOAA, test application of revised BCG.

3.1.c. Prepare validation samples for rating by the data providers and scientists.

3.1.d. Conduct webinars with data providers and territorial and federal coral monitoring program scientists to discuss model performance and to test model revision (model validation).

3.1.e. Finalize fish model based on validation results.

SubTask 3.2*: *Develop final numeric BCG for coral reef benthic macroinvertebrate community in the Caribbean

3.2.a. Revise prototype benthic macroinvertebrate BCG to address expert comments and recommendations.

3.2.b. Using data from USVI, PR and NOAA, test application of revised BCG.

3.2.c. Prepare validation samples for rating by the data providers and scientists.

3.2.d. Conduct webinars with data providers and territorial and federal coral monitoring program scientists to discuss model performance and to test model revision (model validation).

3.2.e. Finalize benthic macroinvertebrate BCG based on validation results.

SubTask 3.3: Develop assessment screening metrics for both fish and benthic macroinvertebrate BCGS

3.3.a. Test both assemblage BCGs for a subset of metrics to use individually or in combination as a screening method to determine if a coral reef is supporting or not supporting aquatic life. The screening tool will be used as an indicator that a site at risk for not supporting aquatic life and more intensive monitoring required.

3.3.b. Present results of analysis to TOCOR, USVI and PR bioassessment program scientists and facilitate discussion on selection of metrics that meet each of their program requirements.

3.3.c. Revise as needed the assessment screening method to address comments from TOCOR, USVI and PR bioassessment program scientists.

SubTask 3.4: Technical Documentation

3.4.a. Prepare technical report that documents method, rationale and process for development of numeric BCGs for fish and benthic macroinvertebrates in the Caribbean and for the screening method.

3.4.b. Revise technical report per comments received from TOCOR.

Task 3. Deliverables

Task	SubTask	Deliverable	Due
3	3.1.a-d	Numeric Fish BCG	Two (2) weeks after receiving final comments from the TOCO
3	3.2.a-e	Numeric Benthic Macroinvertebrate BCG	Two (2) weeks after receiving final comments from the TOCO
3	3.3.a-c	Screening Method	Two (2) weeks after receiving final comments from the TOCO
3	3.4.a-b	Technical Documentation	Two (2) weeks after receiving final comments from the TOCO

Task 4: Technical Consultations (Contract PWS Section 2, Task Areas 2, 3, 4, 5,6, 7)

The contractor shall provide technical support to states through informal technical consultations with US EPA. These activities will be identified to the contractor by the EPA TOCOR via email, teleconference, or web conference. These consultations may include, but are not limited to:

- Exchanging scientific literature,
- Reviewing and providing scientific feedback on a state's field sampling design, analytical methods, and data analysis design;
- The construction and interpretation of ecological models (empirical, numerical),
- Exploring assessment endpoints and conceptual models related to aquatic life, ecosystem and/or watershed condition,
- Facilitating peer-to-peer (i.e., state-to-state) transfer of scientific and technical information,
- The use of biological indicators in the development and implementation (i.e., monitoring and assessment) of numeric criteria,
- The evaluation of state bioassessment programs that seek to employ biological indictors as part of nutrient or other stressor criteria, and
- Development of biological monitoring and assessment tools that may be used to detect nutrient or other stressor pollution at reach and catchment scale as well as global or regional scale stressors such as long-term alteration of hydrology, temperature and forest cover.

US EPA anticipates that the contractor shall participate in and prepare for up to two consultations with US EPA headquarters (HQ) biocriteria staff, US EPA regional staff, and state water quality staff. The scope, objective and schedule for technical consultations shall be defined in detail in writing with the TOCOR and scientific in nature. The contractor shall maintain a written record of all consultations to be made available to the TOCOR upon request.

SubTask 4.1*: *Communication/Kickoff Call

The Contractor shall contact the EPA TOCOR and schedule a kickoff project meeting with the TOCOR upon notification from the TOCOR of a technical consultation.

SubTask 4.2*: *Communication and development of a regular reporting schedule

The Contractor shall establish communication with the EPA TOCOR and develop a regular reporting schedule throughout the period of the technical consultation.

SubTask 4.3*: *Monthly Progress and Financial Reports

Submit and prepare monthly progress reports. The monthly progress report shall include project status, expenditures to date, unexpected problems or concerns, corrective actions, lessons learned, QA/QC activities, and next steps.

SubTask 4.4*: *Coordination and notification

This task requires coordination with other organizations and therefore it is particularly important that the Contractor shall notify the EPA TOCOR of issues, problems, questions, or delays as soon as they become apparent or if they are anticipated.

Task 4. Deliverables

Task	SubTask	Deliverable	Due
4	4.1	Communication/Kick-off call	Within 3 days of consultations
4	4.2	Regular reporting schedule	As requested by the TOCOR
4	4.3	Progress and financial reports	Monthly
4	4.4	Coordination and notifications	Immediately upon knowledge of incident

VIII. Acceptance Criteria:

The Contractor shall prepare high quality deliverables. Deliverables shall be edited for grammar, spelling, and logic flow. The technical information shall be reasonably complete and presented in a logical, readable manner. Figures submitted shall be of high quality, similar to those in presentations developed for national scientific meetings and should be formatted as jpeg or png files. Additional requirements specific to this TO are as follows: Electronic deliverables must be in an original file format that can be supported by EPA after the end of the Period of Performance of the TO. The standard office software at EPA is MS Office. Text deliverables shall be provided in Microsoft Word 2010 or compatible format.

Appendix A. Tetra Tech SOP for Statistical Analyses

Standard Operating Procedure TT-FFX-SOP-Q-002

Statistical Analyses

Prepared by:	Name Jon Harcum, Ph.D.	Title Environmental Engineer
	Signature Jon Harcum	Date
Approved by:	Name John Hochheimer, Ph.D.	Title Technical Monitor
	Signature	Date 3/5/17
Approved by:	Name Susan Lanberg	Title QA Officer
	Signature	Date

Scope and Applicability: The Tetra Tech Project Manager, Statistical Analyst, QA Officer, and QC Officer should refer to this procedure to ensure that the quality assurance/quality control (QA/QC) requirements set by our clients are met. Statistical analysis of data covers a wide range of calculations and graphical visualization techniques. Relevant QA/QC practices for statistical analyses include ensuring that the analyses are correct, reproducible, and transparent. To ensure that we meet the QA/QC requirements set by our clients, statistical calculations must undergo QC reviews and those reviews must be documented in the project files. The Tetra Tech Project Manager and QA Officer will communicate to the Statistical Analyst whether specific documentation of QC reviews is required for a particular task.

The appropriate level of statistical analysis and corresponding level of QC review will vary with project goals, available data, resources, and the decisions to be made. At the beginning of a particular project, the Statistical Analyst will provide recommendations to the Tetra Tech Project Manager regarding statistical methods to be used for analyzing the data. At this time, the Statistical Analyst and Project Manager should discuss the approximate level of effort needed for the various analyses and corresponding level of QC review required. Follow-up discussions should be held throughout the duration of the project, as needed, to clarify the analyses to be performed, level of QC review needed, and level-of-effort required.

- It should be noted that analyses that are expected to be used to inform future, more detailed analyses can be performed with a cursory-level QC review so long as work products are identified as such in their transmittal to the client and in progress reports.
- Analyses that directly inform decisions/actions (e.g., remediation, compliance decisions, regulatory action, source control, capital investment) require a higher, standard-level QC review.

This document describes the following topics as related to ensuring the quality of Tetra Tech's statistical analyses: method selection, best practices, and QC.

Responsibility and Personnel Qualifications: The Tetra Tech Project Manager supervises the overall project and is responsible for coordinating project assignments; establishing priorities and schedules; ensuring completion of high-quality projects within established budgets and schedules; providing guidance, technical advice, and evaluating the performance of those assigned to the project; implementing corrective actions; preparing or overseeing preparation and review of project deliverables; and providing support to the client in interacting with the project team, technical reviewers, and others to ensure that technical quality requirements are met in accordance with the client's objectives. The Statistical Analyst is responsible for performing the statistical calculations and analyses and the QC Officer is responsible for checking those activities. A QC Officer is a technical staff member who is familiar with the project tasks but does not participate in the task or subtask that he or she checks. The QA Officer with assistance from the assigned QC Officer, will monitor QC activities to determine conformance with project QA/QC requirements. The Tetra Tech Project Manager and QA Officer will communicate to the Statistical Analyst whether specific documentation of QC reviews is required for a particular task.

Procedures

1. Method Selection: Based on the characteristics of available data and the project's needs, the Tetra Tech Project Manager, in consultation with the client and the Statistical Analyst, will determine whether common exploratory summary statistics and/or standard graphical presentations will be needed for a particular project, or whether more advanced predictive procedures (e.g., applying a range of hypothesis tests, applying multivariate tools, developing empirical models) will be required. Some examples of various procedures are listed below.
    - Common summary statistics include counts of observations and distribution characteristics (e.g., mean, standard deviation, coefficient of variation, variance, median, percentiles).
    - Standard graphical presentations (e.g., distribution plots, scatter plots, boxplots, time series).
    - Parametric and non-parametric hypothesis tests (e.g., t-test, analysis of variance, Kruskall-Wallis).

- Multivariate tools (e.g., principal components analysis, clustering analysis, canonical correspondence analysis, discriminant analysis, non-metric mulitdimensional scaling).
- Models (e.g., linear and non-linear regression, general additive models, general linear models, Bayesian hierarchical models).

When deciding which statistical procedure to apply to any data set, it is essential to consider the characteristics of the data, which will help determine the appropriate statistical analysis. Some common characteristics of data include one or more of the following:

- Presence of outliers, extreme low or high values that occur infrequently, but usually somewhere in the data set (outliers on the high side are common) resulting in skewed distributions.
- Variance heterogeneity.
- Non-normal distribution.
- Small sample size.
- Censored data – concentration data reported above or below one or multiple detection limits or reporting values.
- A lower bound of zero (e.g., no negative concentrations are possible).
- Missing values.
- Irregular sampling.
- Strong seasonal patterns.
- Autocorrelation – consecutive observations strongly correlated with each other.
- Dependence on other uncontrolled or unmeasured variables – values strongly co-vary with such variables as streamflow, precipitation, or sediment grain size.
- Measurement uncertainty.

Common Tools/Software: There are a wide variety of computer tools/software available to support statistical analyses including spreadsheets (e.g., Excel), databases (e.g., Access, SQL), commercial statistical packages (e.g., SAS, Minitab, Systat), customized software (software created by a state/federal agency or a third party vendor designed for a particular analysis, e.g., ProUCL, EPIWEB), and programming code (e.g., FORTRAN, C++, Python, R). Hand calculations can also be used.

The functionality of these tools overlaps, yet different numerical results are sometimes computed when using different tools. For example, a key part in estimating percentiles is to assign ranks to the observed data. Some spreadsheet software programs assign the minimum rank to tied values rather than assigning a rank that is equal to the median of the ranks if the observations had not been tied. Other commercial software may include multiple formulas for computing percentiles, which the user can select. The outcome is that different percentiles might be computed among different software packages. Similarly, different analysts can compute different numerical results when applying similar steps, but simply in a different order (e.g., the logarithm of the average is not equal to the average of the logarithms). It is important that the original analyst and person performing QC checks be aware of these potential differences and their impact on the analyses and independent checking of results. *Overall Justification and Documentation of Methods Used*: Common summary statistics and standard graphical presentations that follow normal practices for the type of data being evaluated require little or no justification for their usage. Method selection for hypothesis testing, multivariate procedures, model development, or more advanced procedures should be made by an experienced analyst with justification included in the corresponding report. Citing similar analyses available from applicable guidance/methods documents or peer-reviewed literature is sufficient. Methods selected from the Internet, gray literature, software literature, or presentations require additional narrative to document why a particular method is, or might be expected to be, appropriate.

2. Best Practices: This section provides a list of best practices that can be implemented to reduce errors in statistical analyses and improve the overall work product. It is the responsibility of the Tetra Tech Project Manager and delegated Statistical Analyst to identify which practices are appropriate for a particular task.

- *Overall*:
  - Maintain original copies of source data, related metadata, and the 'ready-to-analyze' data sets. See the Secondary Data Management SOP for more information on data organization and management. Use a naming convention for files that is understandable to you and others, and is designed in way that helps ensure that version control is maintained throughout the project (e.g., use of dates, version numbers, draft, final).
  - Develop a written technical description of the analysis. This description can be written before beginning analyses and/or developed as a living document throughout the course of the project.
  - Identify analysis milestones where data should be exported/saved to improve transparency and reproducibility, as well as for QC analyses and record keeping.
  - Perform statistical analyses in a similar fashion throughout the project. Document deviations in the technical description of the analyses.
  - Document the name, version, and, where applicable, the source code of the software used to perform analyses. This is applicable for commercial and open source software.
  - Give titles to objects in the spreadsheet, database, or software that lend an understanding to the purpose of the object. For example, a database query entitled 'selectData_v02' might be a useful object title for the second version of a query that selects data from a primary source table.

- *Hand Calculations*:
    - Hand calculations should be legible and document their purpose.
    - Scan hand calculations so they can be maintained as electronic documents with other documentation.
- *Spreadsheets*:
    - Include a documentation tab that includes information about the spreadsheet as a whole and a description of the other tabs.
    - Organize tabs from left to right in the same order as the analysis steps.
    - Organize calculations within a tab from left to right and/or top to bottom.
    - Make judicious use of named cells and relative/absolute cell addresses to allow maximum use of 'fill-down' and 'fill-right' options.
    - Limit cell and font styles for highlighting information that could be derived from examining the data. For example, it is an acceptable practice to set a cell color to "yellow" to help visualize all p-values less than 0.05. It is not a typically accepted practice to highlight statistically significant regression slopes but not show/include the actual p-values.
- *Commercial Statistical Packages*:
    - Document the name and versions of the software used.
    - Document the steps and settings used to implement calculations that are menu/interactively implemented.
    - Develop macros to implement repeated tasks.
- *Customized Software*:
    - Document the name and versions of the software used.
    - Document the steps and settings used to implement calculations that are menu/interactively implemented. (Note that it is a common practice for software packages to be developed by a third party on behalf of a state or federal agency to perform a very specific set of analyses that are not directly available in commercial software. While these software packages may be well tested for the primary work flow, they may not be as well tested or error proof, if used in a non-conventional manner. Therefore it important that the analyst have an understanding of the basic work flow of the software package and document its usage.)
- *Programming Code (e.g., FORTRAN, C++, Python, R)*
    - Maintain all source code, and if applicable compiled code, used to perform all analyses for documentation and future use. This allows for transparency and repeatability of the analysis.
    - Where practicable, repeat the analyses with a separate tool to verify the results or code and/or independently unit test the source code.

Pertinent QA and QC Procedures

1. The appropriate level of QC will vary with project goals, available data, resources, technical approach, and the decisions to be made. The principal QC questions include the following:

   - Was an appropriate method chosen and applied?
   - Were the statistics computed and graphics created correctly?
   - Were the statistics and graphics representative of the data?
   - Were method assumptions met?
   - Were the results presented correctly?

2. Selection of a particular method depends on the data and the analysis objectives. Calculating summary statistics and developing basic graphics can normally be performed by any basic environmental consultant/staff member. Exceptions might include calculations with censored data or other non-standard data. Advanced statistical calculations and related output (tabular, graphic, etc.), including, but not limited to, hypothesis testing, multivariate tools, empirical models, and statistical simulations will generally benefit from oversight by an experienced analyst. However, it should be noted that multiple methods might be applicable for a given project and set of data (see Overall Justification and Documentation of Methods Used section above).

3. As described in the introductory section of this document, analyses that are expected to be used to inform future, more detailed analyses can be performed with a cursory-level QC review so long as work products are identified as such in their transmittal to the client and in progress reports. While a cursory-level QC review could include some independent checking of calculations, a cursory-level review may also be limited to reviewing selected sections of a technical report that focus on the data summary, technical approach, and results sections.

4. For statistical calculations performed using analysis software for which the results will be used to directly inform decisions/actions (e.g., remediation, compliance decisions, regulatory action, source control, capital investment), calculations will be independently checked using a standard-level review. As used here, independent calculations can refer to a different analyst performing the same analysis, or they may refer to the same analyst performing the same analysis using a different software tool. Some projects might require complete independent checking of all calculations. This requirement, or even standard-level QC, could cause a significant resource burden in projects that involve multiple iterations and modifications. Thus, the Statistical Analysts should confer with the Project Manager to confirm the best timing for QC checks to best use the available budget.

5. With today's computer technologies, it is more appropriate in some instances to perform targeted checking rather than rely on a fixed "10 percent of all calculations" rule when performing independent calculations. A standard-level review consists of up to 10 percent independent recalculations of computations and graphs, but no less than two examples of each computed statistic and two examples of each graphic type. More calculations (up to 10 percent) should be reviewed if data sets or points are processed individually while fewer

checks (no less than two examples of each computed statistic and two examples of each graphic type) are appropriate for automated to semi-automated procedures. Selection of which statistics and graphs to check should include targeting unique and unusual record types that might stress the calculation and graphing process. All identified calculation errors will be corrected and the Tetra Tech QC Officer will perform a follow-up review of the corrected components to ensure that the errors have been corrected. Where changes are made to previously checked analyses or changes are made to address the results of QC checks, it is normally expected that only the changed/corrected components of the analysis and the dependent, follow-on components would be subject to checking/re-checking. For example, if a change or correction is made to an analysis (e.g., substituting a maximum likelihood technique for a least squares estimation method) then it would not be normally expected to
re-check data transformation steps the led to creating the 'ready-to-analyze' data set. In cases where codes are developed to perform statistical calculations, codes and changes to codes should be checked and tested for reproducibility by a qualified QC Officer, and if possible, run on independent software.

6. In the majority of instances, statistical calculations will be performed using analysis software. In (relatively uncommon) circumstances where statistical calculations are primarily performed by-hand, a Tetra Tech QC Officer will independently recalculate 10 percent of these calculations to ensure they were performed correctly. If more than 1 percent of the data calculations are incorrect, the Tetra Tech QC Officer will independently check the remaining calculations to ensure they are correct. All identified errors will be corrected.

Appendix B. Tetra Tech SOP for Secondary Data

Standard Operating Procedure TT-FFX-SOP-O-001

Secondary Data Management

Prepared by:	Name Alex DeWire	Title Environmental Scientist
	Signature	Date 3/9/17
Approved by:	Name John Hochheimer, Ph.D.	Title Technical Monitor
	Signature	Date 3/9/17
Approved by:	Name Susan Lanberg	Title QA Officer
	Signature	Date

Scope and Applicability: This procedure provides an overview of secondary data processing and management techniques. Secondary data are data that were collected under a separate effort for some other purpose, whereas primary data are original data collected for a specific project. Secondary data analyses are becoming increasingly common because technological advances have made it possible to store and remotely access large amounts of data. Secondary data processing can be used to further refine and process data compiled from existing data sources. Information on evaluating secondary data sources for quality is provided in the quality assurance project plan **(QAPP)** or equivalent documentation prepared for a particular project.

This procedure acknowledges that standard practices and protocols vary temporally and differ among various monitoring groups, states, and agencies. Secondary data processing techniques aim to detect and account for inconsistency in a data set compiled from multiple sources. The goal is to improve the comparability and consistency of secondary environmental monitoring data used for a particular project.

This document describes the following topics as related to ensuring the quality of Tetra Tech's secondary data management: data acquisition and documentation, data quality considerations, data organization, and data transformation. A quick reference list of common steps used for data management and processing developed specifically for water quality data, is also included as Attachment 1.

Responsibility and Personnel Qualifications: The Tetra Tech Project Manager, Data Manager, Quality Assurance (QA) Officer, and Quality Control (QC) Officer should refer to this procedure to ensure that the QA/QC requirements set by the client are met. The Tetra Tech Project Manager supervises the overall project and is responsible for coordinating project assignments; establishing priorities and schedules; ensuring completion of high-quality projects within established budgets and schedules; providing guidance, technical advice, and evaluating the performance of those assigned to the project; implementing corrective actions; preparing or overseeing preparation and review of project deliverables; and providing support to the client in interacting with the project team, technical reviewers, and others to ensure that technical quality requirements are met in accordance with the client's objectives. The Tetra Tech Data Manager is responsible for performing the data processing and management activities and the Tetra Tech QC Officer is responsible for checking those activities. A QC Officer is a technical staff member who is familiar with the project tasks but does not participate in the task or subtask that he or she checks. The Tetra Tech QA Officer, with the assistance of the assigned QC Officer, will monitor QC activities to determine conformance with project QA/QC requirements. The Tetra Tech Project Manager and QA Officer will communicate to the Tetra Tech Data Manager whether specific documentation of QC reviews is required for a particular task.

References:

Boslaugh, S. 2007. *Secondary Data Sources for Public Health: A Practical Guide*. Cambridge University Press.

Chapman, A.D. 2005. *Principles of Data Quality*, Version 1.0. Report for the Global Biodiversity Information Facility, Copenhagen. http://niobioinformatics.in/pdf/workshop/Data%20Quality.pdf.

Edwards, P.J. 1986. *Conversion Factors and Constants Used in Forestry, with Emphasis on Water and Soil Resources*. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. NE-GTR-113. November 1986. 12 p. http://www.treesearch.fs.fed.us/pubs/4159.

U.S. EPA (U.S. Environmental Protection Agency). 2009. *EPA New England Quality Assurance Project Plan Guidance for Environmental Projects Using Only Existing (Secondary) Data.* EPA-820-S-10-001. U.S. Environmental Protection Agency New England, Quality Assurance Unit, Office of Environmental Measurement and Evaluation. http://www.epa.gov/region1/lab/qa/pdfs/EPANESecondaryDataGuidance.pdf.

U.S. EPA (U.S. Environmental Protection Agency). 2012. *Guidance for Evaluating and Documenting the Quality of Existing Scientific and Technical Information Addendum to: A Summary of General Assessment Factors for Evaluating the Quality of Scientific and Technical Information*. Prepared for the U.S. Environmental Protection Agency, Science and Technology Policy Council, Washington, DC. http://www2.epa.gov/sites/production/files/2015-05/documents/assess3.pdf.

U.S. EPA (U.S. Environmental Protection Agency). 2014. *Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams*. EPA/600/R-13/170F. Global Change Research Program, National Center for Environmental Assessment, Washington, DC. Available from the National Technical Information Service, Springfield, VA, and online at https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=280013&CFID=87634392&CFTOKEN=78487573.

Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A. 2006. *Guidelines and Standard Procedures for Continuous Water-Quality Monitors—Station Operation, Record Computation, and Data Reporting.* U.S. Geological Survey Techniques and Methods 1–D3, 51 p. + 8 attachments. http://pubs.water.usgs.gov/tm1d3.

Procedures

1. Data Acquisition and Documentation: Data acquisition involves the process of obtaining and documenting data of various types (e.g., water quality sampling data, spatial data, remote sensing imagery, survey results, 303(d) impairment or 305(b) assessment data, TMDLs, discharger data) using search criteria for the project determined in consultation with the client. Data acquisition must be a repeatable and transparent process. At the beginning of a project, the Tetra Tech Project Manager will consult with the Tetra Tech QA Officer to determine applicable documentation requirements. Data Managers must automate and document each aspect of data acquisition. Data Managers should avoid manual transcription (non-automated data processing) because of the potential to introduce error into the data set. However, automated processes must be properly checked and verified to ensure error-free results.

   The important aspects of data documentation include keeping records of the data source (e.g., URL, agency providing the data, version), the access date, and the access procedure. At the beginning of the project, the Tetra Tech Project Manager will consult with the Tetra Tech QA Officer to determine applicable documentation requirements. Screen captures of search results (refer to Figure 1) can be a quick and effective way to document aspects of the download procedure. Figure 1 is an example of a screen capture of selection criteria entered in the Water Quality Portal: State = "Kentucky"; Site Type = "Stream" and "Lake, Reservoir, Impoundment"; Sample Media = "Water"; Characteristic Group = "Biological" and "Nutrient"; Date Range = "01-01-2003" to "12-31-2013"; and Database = "STORET" and "NWIS". Alternatively a README text file or word document can be saved with the original data to document this information. If data are acquired via e-mail or file transfer protocol (FTP), save a copy of the original e-mail or FTP access instructions.

2. Data Quality Considerations: At the beginning of a project, the Tetra Tech Data Manager will consult with the Tetra Tech Project Manager and QA Officer for applicable data quality considerations. The advantages of using secondary data include cost and time savings, more extensive data availability, and the potential for analysis by experts not available at smaller scales. However, secondary data have inherent disadvantages because the data were not

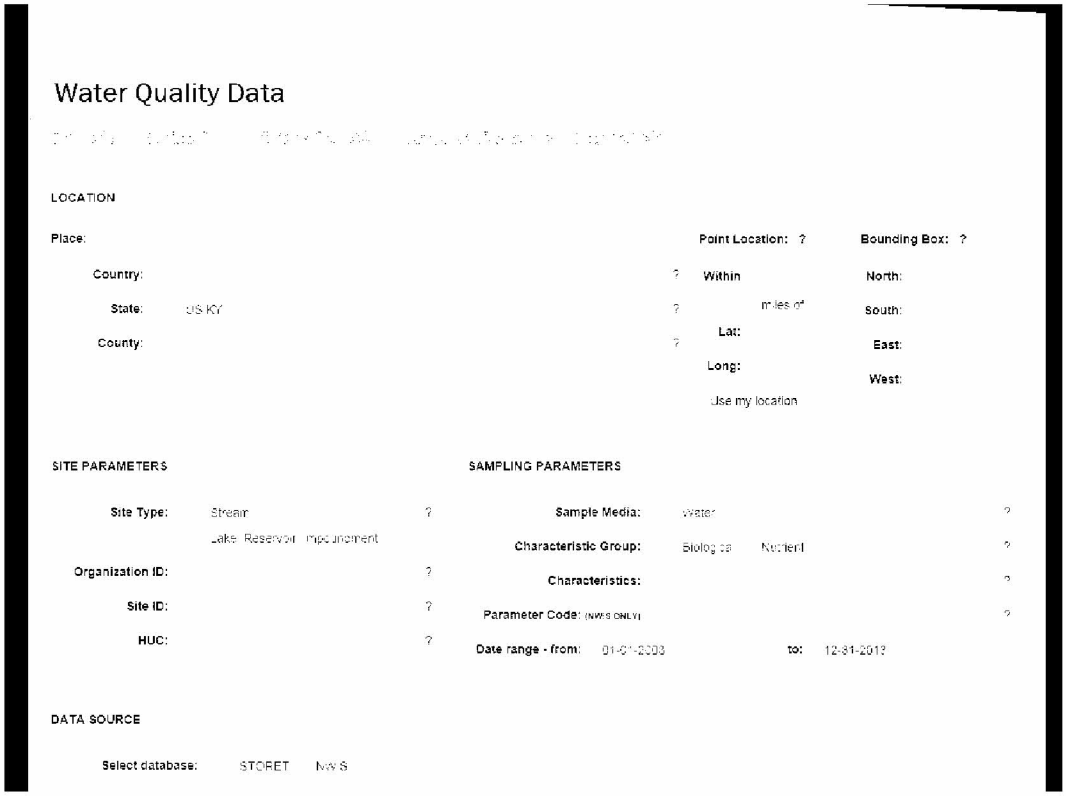

Figure 1. Example screen capture of search criteria selections in the Water Quality Portal[1]

collected by those conducting the analysis and were often not collected to answer the specific question(s) of the current analysis.

For example, data might have been collected for different variables, geographic regions, or sampling frequencies. In addition, because the analyst did not participate in the sampling design or sampling process, the methods and quality of analysis might be unknown. Data might have been collected using different sampling techniques (grab sampling versus composite sampling or random sampling versus targeted sampling). The laboratory or sampling processing methods might also have differed. Differences in technique or documentation can contribute to variability in the data set when multiple secondary data sources are combined for an analysis. Errors in spatial position and taxonomic identification are particularly common in environmental data (Chapman 2005).

The amount of documentation associated with a particular source often varies widely. Documentation of the source, including metadata documented in project reports, validation reports, and any database information, should be maintained along with the data. Research into the origin and documentation of a data source might be necessary to properly evaluate the data source. Potential sources for this documentation might include the website for the agency or group that collected the data, published reports, research articles, and personal communication with the original researcher or monitoring group staff.

[1] http://www.waterqualitydata.us/portal.jsp

Consider this series of general questions when evaluating the quality of any secondary data source and the applicability of the data to the current project (Boslaugh 2007):

- What was the original purpose for which the data were collected?
- What kind of data are they, and when and how were the data collected?
- What data processing and/or recording procedures have been applied to the data?

Also consider the following questions, which are more specific to water quality data, when evaluating a water quality data source (USEPA 2009):

- Were the data generated under an approved QAPP or other documented sampling procedure?
- If multiple data sets are being combined, were the data sets generated using comparable sampling and analytical methods?
- Were the analytical methods sensitive enough (detection limits) to meet project needs?
- Is the sampling method indicated (e.g., grab, composite, calculated)?
- Was the sampling effort representative of the waterbodies of interest in a random way, or could bias have been introduced by targeted sampling?
- Are the data qualified? Are sampling and laboratory qualification codes or comments included? Are the qualification codes defined?
- Is sufficient metadata available about variables like sampling station location, date, time, depth, rainfall, or other confounding variables?

Specific evaluation criteria for each parameter being considered should also be applied across all sources. Although many water quality data sets include QC samples labeled as duplicate, split, spiked, blank, and so forth; re-checking QC samples is beyond normal practices for secondary data analyses. Rather, it is expected that project-specific QAPPs or similar documentation describing the performance criteria evaluated and met are available for data obtained from peer reviewed sources or from federal, state, or local government reports or data compilations. If this documentation is not readily available, Tetra Tech will consult with the client to determine how much effort should be expended to find reports or metadata that might contain that information. Nevertheless, establishing minimum data requirements for secondary data analyses is often valuable. For example, water chemistry data might require locational information, date, time (optional), depth (optional), chemical name, units, numerical result, and data qualifiers. Specific requirements would depend on project specific needs. For example, it might be necessary to identify outliers or changes in analytical methods. In those cases where requested by the client, QC samples can be used to double- check sample accuracy (e.g., whether duplicate samples are within 15 percent of the corresponding sample).

The National Environmental Methods Index (NEMI)[2] provides a searchable compendium of environmental methods. Different scientific methods can be compared using the method summaries, which also include literature citations. Generally, parameters monitored using different methods should not be combined unless the techniques are documented to be scientifically comparable. EPA also has compiled training materials to detect improper laboratory practices when working with monitoring data.[3]

3. Data Organization: After acquisition, data should be organized and stored. The original unaltered data and "as analyzed" data files should be archived to ensure replicability of the work. Data sets are constantly being updated, so without the original data, replicating an analysis is often impossible. If you are combining data from multiple sources, include information documenting the source of the data in spreadsheets or databases. For water quality data, generally seek to organize data into one of the following hierarchical structures: (1) *source* → *station* → *sample* or (2) *source* → *station* → *sample* → *result* so the data are ready for a variety of analyses.

   A relational database, such as Microsoft Access or an Oracle-based system, is an efficient method used to organize multiple related tables. For water quality data, these tables can include station-level tables, sample-level tables, and lookup tables. A primary key or unique identifier, such as a numerical field or a composite primary key made up of multiple fields (e.g., station-sample-date-time-depth), should be assigned to each record. Each table should have a primary key. Foreign keys are fields in one table that uniquely identify a row in another table, often called a lookup table. Figure 2 provides an example of sample-level and lookup relational tables with the primary keys and foreign keys identified. Referential integrity should be maintained such that each foreign key corresponds to the value of a primary key or a null value in a lookup table.

Sample ID	Parameter	Result	Remark
1	Total Nitrogen	1.4	DQ
2	Total Nitrogen	1.4	
3	Nitrate	0.5	
4	Total Nitrogen	2.4	DQ
5	Total Nitrogen	2.4	
6	Total Phosphorus	0.08	T

Remark	Description	Action
W	cloudy	NA
DQ	Duplicate Quality Assurance Sample	REMOVE
T	Sample exceeding holding time	REMOVE
?	Data should be rejected	REMOVE
*	Exceeded MDL	Flag

Figure 2. Example of relational tables with primary and foreign keys

A disciplined file structure and file naming convention can improve version control management. Label files with unique identifiers such as dates or other indicators of version control. Include a documentation table that identifies the database objects (tables, queries,

[2] www.nemi.gov
[3] http://www.epa.gov/quality/trcourse.html#monitoring

reports, etc.). Maintain the original data in a read-only database and 'link in' to the analysis database to prevent accidental changes to original data.

Large (e.g., multiple-gigabyte) files sizes are increasingly common, especially with remote sensing imagery, spatial data, or large databases. Consider the storage and backup requirements of these large files. For example, you might need a separate server to accommodate the data needs for a project. If you are working with multiple people, consider the implications of file storage choices for file transfer. Spatial data management has some unique considerations discussed in a separate Geospatial and Data Management QA/QC Procedures document.

Sample-level water quality data are often stored in a vertical format with a column for parameter or characteristic name and a column for result values, as shown in Figure 3. After data transformations, but before statistical analyses, it is often more convenient and space- efficient to convert the data to a horizontal format, in which each parameter of interest has its own column and results for that parameter are reported in the parameter column. This approach allows for simpler identification of paired sampling data (samples taken from the same station-date-time) for multiple parameters, which in turn makes identifying relationships among parameters possible.

Vertical Format

Date/Time	Characteristic	Result
1/1/2000 15:00	Nitrogen, Total	1.5
1/1/2000 15:00	Nitrate	0.8
1/1/2000 15:00	Phosphorus, Total	0.5
1/1/2000 15:00	SRP	0.1
1/1/2000 15:00	Orthophosphate	0.2
6/1/2000 9:00	Nitrogen, Total	2.2
6/1/2000 9:00	Nitrate	1.3
6/1/2000 9:00	Phosphorus, Total	0.2
6/1/2000 9:00	SRP	0.1
6/1/2000 9:00	Orthophosphate	0.1

Horizontal Format

Date/Time	Nitrogen, Total	Nitrate	Phosphorus, Total	SRP	Ortho-phosphate
1/1/2000 15:00	1.5	0.8	0.5	0.1	0.2
6/1/2000 9:00	2.2	1.3	0.2	0.1	0.1

Figure 3. Example of water quality data in vertical (left) and horizontal (right) format

Effective data organization can improve the efficiency with which data can be checked for errors, processed, transformed, and documented. Sorting by location, source, parameter, or other column allows error-checking and transformation to be automated, which improves not only efficiency but also QA.

Aligning matching records can be arduous if not already performed. For example, StationID might differ among sampling visits and would need to be checked using latitude/longitude information (which should be associated with each station). When combining data sets, checks of additional records for near-concurrently collected samples should be performed. These additional records could include chemical species, taxonomic names, and dates. For example, if habitat data were collected on one day and fish were collected 2 days later, there should be an indicator that those data are (or are not) comparable for analysis.

4. Data Transformation: After acquiring the data, archiving the original unaltered data, performing QC checks, and organizing the data, the data often need to be transformed or processed to put them in a comparable format. Data transformation should be organized, systematic, repeatable, and automated as much as possible to reduce the chance of error and minimize the level of effort common to manual transformation.

   This task often involves manipulating the data from the original data source to a 'ready-to- analyze' data set. The original data source can be one to multiple files with the same or different data structure.

Pertinent QA and QC Procedures

1. Relevant QA/QC practices for secondary data management include ensuring that the data processing steps are correct, documented, well organized, reproducible, and transparent. To ensure that we meet the QA/QC requirements set by our clients, data processing steps must undergo QC reviews and those reviews must be documented in the project files. The Tetra Tech Project Manager and QA Officer will communicate to the Data Manager whether specific documentation of QC reviews is required for a particular task.

2. The appropriate level of secondary data management and corresponding level of QC review will vary with project goals, available data, resources, and the decisions to be made. At the beginning of a particular project, the Data Manager will provide recommendations to the Tetra Tech Project Manager regarding methods to be used for processing and managing the data. At this time, the Data Manager and Project Manager should discuss the approximate level of effort needed for the various processing steps and corresponding level of QC review required. Follow-up discussions should be held throughout the duration of the project, as needed, to clarify the analyses to be performed, level of QC review needed, and level-of-effort required.

   - It should be noted that cursory level compilations of data that are used to inform whether more robust data compilations can be prepared can be developed with minimum QC review so long as intermediate work products are identified as such in their transmittal to the client and in progress reports.
   - Data compilations that directly inform decisions/actions (e.g., remediation, compliance decisions, regulatory action, source control, capital investment) require a higher level of QC review.

3. For replicability and QA, maintain a copy of the raw, unaltered downloaded data and related metadata, including variable names/definitions. These raw data can also be important in troubleshooting processing errors introduced during the analysis and in maintaining version control. Data are increasingly dynamic with real-time data uploads and can be updated by data owners at any time. Also, maintain the 'ready-to-analyze' data sets. A 'ready-to-analyze' data set refers to the data set after all processing and transformations have been completed, prior to analysis. At a minimum, the original data, the 'ready-to-analyze' data, and all project deliverables should be electronically stored where automated backups are made on at least a daily basis for the purposes of catastrophic recovery. This can include

office servers or cloud-based solutions. Test analyses and temporary files do not require this type of storage or backup.

4. Other QC checks could leverage the spatial aspect of the data. Stations should be mapped to verify that the data fall in the correct political boundary, ecoregion, waterbody type, or other descriptive spatial factor. Data that reportedly reflect sampling of a lake in Kansas but have coordinates in the Pacific Ocean should call the accuracy of the data and/or the coordinates into question, as should the occurrence of a fish species in a lake in Kansas, not found in inland lakes. Continuous data have a different set of quality concerns such as time stamps, drift in measurements over time, and trimming of the period of record to eliminate records that are out of water, choked in sediment, or exhibiting drift. These concerns are not addressed in this Tetra Tech QA/QC document. For further information on continuous data quality concerns, refer to draft guidance from USEPA and USGS on this topic (USEPA 2014; Wagner et al. 2006).

5. Different data sets can have different naming conventions, units, etc., that need to be unified. The principal QC questions include the following:
   - Was the process documented?
   - Were all data files processed?
   - Were all data records processed (e.g., no dropped records)? If not, were excluded data justified?
   - Were transformation and reshaping steps implemented correctly?

6. As described earlier in this document, cursory level compilations of data that are used to inform whether more robust data compilations can be prepared can be developed with a cursory-level QC review so long as work products are identified as such in their transmittal to the client and in progress reports. With the exception of these cursory-level data compilations, independent checks of data compilations should be performed to ensure we meet the client's QA requirements. Applicable QC checks for data reshaping and transformations tasks are summarized in Table 1.

Table 1. Applicable QC checks for data reshaping and transformations

QC #	Description	Cursory Level Review	Standard Level Review
1.1	Confirm that the reshaping and transformation steps are documented with the data.	X	X
1.2	Confirm that the files processed and record counts of the end product meet expectations.	X	X
1.3	Review meta information prepared by the original analyst that documents transformations and reshaping.	X	X
1.4	For each different file type (i.e., a file with different structure or legacy), confirm the first, last, and a selected middle portion of the data were transformed and reshaped correctly.*		Up to 10% of processed data files, but no less than two data files of each type**

QC #	Description	Cursory Level Review	Standard Level Review
***Evaluating the first and last portions of data helps confirm that no records were accidentally dropped during processing. Selection of the middle portion of the data to check should be done by targeting unique and unusual record types that might stress the transformation and reshaping processing. ** More files should be reviewed (up to 10%) if files are processed individually while fewer files are appropriate for automated to semi-automated procedures.**			

This section describes cursory- and standard-level QC checks that should be performed. Some projects might specify complete independent checking of an entire data compilation. This specification or even standard-level QC could cause a significant and, perhaps unnecessary, resource burden in projects that involve multiple iterations and modifications; thus the Data Manager should confer with the Project Manager to confirm the most cost-effective and efficient process for QC checks.

For data compilations that will be used to directly inform decisions/actions (e.g., remediation, compliance decisions, regulatory action, source control, capital investment), processed data will be independently checked using a standard level review. This standard review consists of independently checking each different file type (i.e., a file with different structure or legacy) and confirming the first, last, and a selected middle portion of the data were transformed and reshaped correctly. Evaluating the first and last portions of data helps confirm that no records were accidentally dropped during processing. Selection of the middle portion of the data to check should be done by targeting unique and unusual record types that might stress the transformation and reshaping processing. More files (up to 10 percent) should be reviewed if files are processed individually while fewer checks (no less than two data files of each type) are appropriate for automated to semi-automated procedures.

All identified data processing errors will be corrected and the Tetra Tech QC Officer will perform a follow-up review of the corrected components to ensure that the errors have been corrected. Where changes are made to previously checked compilation or changes are made to address the results of QC checks, it is normally expected that only the changed/corrected components of the compilation and the dependent, follow-on components would be subject to checking/re-checking. For example, if a change or correction is made to an analysis (e.g., substituting a maximum likelihood technique for a least squares estimation method) then it would not be normally expected that data transformation steps that led to creating the 'ready-to- analyze' data set would need to be re-checked.

Frequently, data column names as well as values (e.g., parameter names, comment fields, and result values) are not consistent between different data sources or even within a single source. A more detailed description of data source fields common to water quality data is provided in Attachment 2. To combine data while maintaining the original data, it is good practice to create additional user-specified fields to represent common parameters, standardized comments, and comparable values. Creating user-specified fields allows for correcting errors and performing transformation while retaining the original data in separate fields. Thus, the opportunity to go back to the original data is maintained. Maintaining documentation of data transformation and error correction is especially important when the processes are being performed by people other than the primary data collector.

Creating user-specified fields provides an opportunity to convert units to like units, standardize parameter names, interpret comment fields, convert non-detect values, or institute other data transformations. For instance, a user-specified data qualifier field might be used to flag or exclude blank samples or samples with non-numeric characters in the value field. Figure 4 provides an example of how user-specified fields might be used to convert field names and units and interpret comment fields. Another important use for user-specified fields is creating a column that documents the original source and the row ID of the original source when merging data, so that if systemic issues are found in a source, they can be resolved and processed more effectively. A quick reference guide of procedures to process water quality data is provided in Attachment 1.

Sample ID	Parameter	Result	Units	Comment	PARM	RESULTVALUE (mg/L)	REMARK
1	Total Nitrogen	1.4	mg/L		TN	1.4	KEEP
2	Nitrogen	19000	µg/L	Sampler Error	TN	19	REMOVE
3	Nitrate	0.8	mg/L	Estimated	NO3	0.8	REMOVE
4	Nitrogen as N	2.4	mg/L		TN	2.4	KEEP
5	Total Nitrogen	2400	µg/L		TN	2.4	KEEP
6	Nitrate as N	500	µg/L		NO3	0.5	KEEP

Figure 4. Example user-specified fields

Unintended data duplication is frequently present in water quality data sets. It might be the result of obtaining the same data from different sources, or simply data entry error. This phenomena, should not be confused with field or laboratory duplicate samples which are commonly performed for QA/QC purposes, including evaluating data precision. Unintended duplication can be present within a single data source or among different data sources. Merging two data sets sometimes creates new inconsistencies and duplication. Unintended duplication can skew and bias data. Duplicate values should be flagged and screened from the analysis as much as possible.

Some samples might resemble duplicate entries but actually have different depths, times, or other distinguishing features. If the only fields that are different are descriptive fields, such as comment fields, that might be an indicator of duplication. The organization ID and sampling name can be good indicators that duplication is present, but also look for duplicate values in the data over the same time frame. For example, several identical numerical values on the same day might indicate duplicate data. Sorting the data chronologically and looking for duplicate sample results is one way to begin to identify duplication. Excel has features to identify and highlight duplicate values in a field; when the data are sorted chronologically, Excel can identify potential duplicates. Duplicate records should be flagged using a user-specified field but generally not deleted. Simply deleting unintended duplicate data (i.e., not field or laboratory duplicate samples), rather than flagging and excluding the data, creates a potential for error and data loss that is difficult to identify.

Attachment 1. Quick Reference Guide of Procedures to Process Water Quality Data

These procedures include examples of the types of checks that are performed—not every check to possibly perform. Site-specific steps will apply to many data sets. These steps do not necessarily need to be performed in sequential order and may be iterative.

✓ **Data Acquisition/Organization**

Acquire data and companion metadata. Maintain a copy of all original files. Document the data source, access date, and the download procedure.

Start a recording sheet to record decisions and selections to review for quality control and data archive. Organize data in a spreadsheet or relational database. Organize data using a hierarchical structure (e.g., source→station→sample or source→station→sample→result).

Data formatting

- Convert "as text" values to numbers. Check for non-numeric characters in numeric fields.
- Label all blank cells as blanks to avoid conversion to zero, remove all inappropriate zeros (e.g., chemistry methods rarely measure a true 0, if they have an MDL).

Review data dictionaries and field names before combining data from multiple sources into a spreadsheet or database format—do not assume that field names are equivalent.

Utilize exploratory data analysis techniques such as summary statistics or graphical techniques.

Data Processing

Generally – do not delete data. Add a screening column to track decision-making and remove records. Maintain removed records in separate file with justification.

Compare the geographic/temporal scope of the data to the project objectives—it might not be necessary to process all data from a given data set. Map stations in GIS to further refine and select data based on analysis selection criteria. Conduct quality assurance checks based on spatial location.

Check for unintended duplicate entries (i.e., not field or laboratory duplicate samples). Identify and screen those samples that are duplicates. Check for samples or results that do not have stations.

Interpret data qualifiers and comments (e.g., spikes, blanks, duplicates, holding time, errors). Screen samples based on an interpretation of the data qualifier remark codes.

Check each field for inconsistencies. Screen undesired components. Examples include:

- Coordinates – Are lat/long coordinates in comparable form? Negative values?
- Date/Time – standard format should be used (MM-DD-YYYY). All in same time zone.
- Depth – filled out and in the same units?
- Sample Media/Type – water, groundwater, air, effluent, stormwater, process water

Add user-specified fields to interpret, standardize, and clean up existing fields:

- Waterbody types – interpret and simplify
- Analytes/taxonomy – consistent use of analyte and taxa names
- Analytical method/sample fraction – consider accuracy and comparability of methods
- Units – standardize units and convert values as appropriate

Censored Data – Data that are reported as not detected or below detection limit should be utilized but accounted for statistically. Several methods are available to interpret censored data depending on the analysis. At this stage, maintaining MDLs and PQLs is likely appropriate to provide later analysis flexibility.

Data Transformation

Calculate metrics or new parameters based on the data available. For example:

- Calculate parameter sums or products (e.g., TN as sum of nitrate+nitrite and TKN).
- Calculate TSI, M-IBI, F-IBI, other biological indices.

Outliers – Analyze the data for potential outliers and consider screening those data that are clearly outliers and may introduce bias or error into the data set.

Document the process to ensure quality assurance and reproducibility.

Attachment 2. Data Source Field-specific Water Quality Data Tips

Several fields that provide more information about the sampling process or sampling location are often included with water quality data. These fields might include sample media, sample type, sampling type or location, and waterbody type. These fields might need to be interpreted or transformed to select the data that are of interest to the analysis. Descriptions of common fields and transformations that should be considered include the following:

- **Sample media:** A field or two for sample media (e.g., water, soil, groundwater) are sometimes included. They can be used to verify that the correct query selections were made for the sample media of interest. Sometimes sample subdivisions identify distinctions that should not be included in an ambient analysis (e.g., effluent, process water).
- **Sample type:** A field is sometimes included that identifies routine samples versus duplicate or quality control samples (spike samples, field replicates, laboratory replicates, or other duplicates). Checking routine values against duplicate values can be a valuable quality control check, but also ensure that duplicate values are not included in the data set used for analysis.
- **Sampling type or location:** Fields indicating the type of sampling, such as effluent, ambient, stormwater, baseflow, pipes, finished water, or process water, are sometimes available. Consider the location of the sampling effort. Sampling focused on effluent outfalls or on pristine waters could introduce bias into an analysis, depending on what the purpose of the project is. Sampling type or location can be an important indicator of sampling bias or spatial bias inherent in the data set resulting from opportunistic sampling rather than random sampling.
- **Waterbody type:** An indication of the type of waterbody where the sampling occurred might be included (e.g., stream/river, lake/reservoir, estuary, ocean, wetland, canal, stormwater). This field can be used to further subset sampling data to the data of interest.

Descriptive fields such as temporal indicators (e.g., date, year, time), sample depth, latitude/longitude, or units are often included in varying formats. A description of common fields and transformations that should be considered is provided below:

- **Temporal:** Ensure all date and time fields are in the same format (e.g., MM-DD-YYYY, YYYY-MM-DD). It is recommended that you use military time and account for time zones. It might be helpful to have one field with "Date" and separate fields for "Year," "Month," "Day," and "Time." If a measurement of diurnal fluctuations is not needed in a parameter, averaging data by day might remove some inconsistencies resulting from data without time information or with slightly different times due to different processing labs or data entry error. Searching for dates outside the range of interest or outside reasonable date or time values (e.g., month <1 or >12, day <1 or >31, year <1900, time <0 or >24) can be a helpful screening tool. Having a sampling date is a reasonable minimum requirement for data.

- **Depth:** Depth should generally be a numeric field. Sometimes a surface or bottom indicator is included as well as a numeric depth field (e.g., S, B). It can be helpful, especially in lakes and estuaries, to add a separate text depth column for profile data that indicate surface, depth, or bottom measurements for some parameters (e.g., dissolved oxygen). Depth units should be standardized to a consistent format (feet or meters).

- **Latitude/Longitude:** Ensure that latitude and longitude are reported in a consistent format. Latitude and longitude units are most often reported in degrees, minutes, and seconds (DMS) (e.g., 39°59'56.055"N, 102°3'5.452"W), decimal degrees (DD) (e.g., 39.999012, -102.052062), or sometimes Universal Transverse Mercator (UTM) coordinates (e.g., 13N 751705 4431801). The examples provided are all roughly from the same point on the border of Kansas, Nebraska, and Colorado. To convert from DMS to DD, use the formula: (degrees) + (minutes/60) + (seconds/3600) = decimal degrees. If values are missing, consider digitizing from GIS or geocoding from an address if provided. One of the most frequent errors is omitting the negative sign (-) in decimal degree coordinates from the southern or eastern hemispheres. If all the records are from North America, all the longitude values should include a negative sign. Consider spatial accuracy. With today's standards, be wary of decimal degree data with less than six digits of precision accuracy or seconds reported with less than two digits of precision (although for larger waterbodies less precision might be acceptable). A typical minimum data requirement for station-level data is that the station must have a latitude and longitude measurement as well as the reported datum. Look for extreme values: Latitude should never be outside the range of 90 to -90 degrees; longtiude, 180 to -180.
- **Units:** Standardize units by parameter and among parameters. Check for systematic incorrect reporting of units when converting all values for a parameter to one unit of measurement. Note that laboratories often report results on a weight-per-weight basis, such as parts per million (ppm) or part per billion (ppb). In water samples, 1 ppm is essentially equivalent to 1 mg/L and 1 ppb is equivalent to 1 µg/L unless concentrations are very high (>7,000 mg/L) (Edwards 1986). In addition, µg/L and mg/m^3 can be considered identical in most cases in water samples. Outliers for a parameter might be an indication that data are reported in varying units.

Appendix C. Tetra Tech SOP for Geospatial and Data Management

Geospatial and Data Management

Prepared by: Name [illegible] Title GIS Manager

Signature [illegible] Date [illegible]

Approved by: Name [illegible] Title [illegible]

Signature [illegible] Date 3/4/17

Approved by: Name Susan Lanberg Title QA Officer

Signature [illegible] Date [illegible]

Scope and Applicability: This procedure is designed for analysts and project managers to have quality assurance/quality control *(QNQC)* information readily available during project start up to aid in developing quality assurance project plans (QAPPs), as well as in closing out projects and in documenting QC tasks. Specific procedures are project-specific and require the input of analysts and project managers to determine the best course of QC measures to apply. In most cases, all of the information and procedures described in this document will not apply to each project, but rather project managers can pick and choose which apply to their project. The information described in this document is designed to provide general *QNQC* background material related to geospatial and data management tasks.

Responsibility and Personnel Qualifications: The Tetra Tech Project Manager, Geographic Information System (GIS) Manager, QA Officer, and QC Officer should refer to this procedure to ensure that *QN QC* requirements set by the client are met. The Tetra Tech Project Manager supervises the overall project and is responsible for coordinating project assignments; establishing priorities and schedules; ens uring com pletion of high-quality projects within established budgets and schedules ; providing guidance, technical advice, and evaluating the performance of those assigned to the project; implementing corrective actions; preparing or overseeing preparation and review of project deliverables; and providing support to the client in interacting with the project team, technical reviewers, and others to ensure that technical quality requirements are met in accordance with the client's objectives. The Tetra Tech Project Manager will have the primary day-to-day contact with the client Project Manager. This approach allows the client to work directly with the person conducting or supervising the project. The Tetra Tech

GIS Manager will supervise the geospatial information operations performed for the project and the Tetra Tech QC Officer is responsible for checking those activities. A QC Officer is a technical staff member who is familiar with the project tasks but does not participate in the task or subtask that he or she checks. The Tetra Tech QA Officer, with the assistance of the assigned QC Officer, will monitor QC activities to determine conformance with project QA/QC requirements.

Procedures

1. Project Setup Procedures: The Tetra Tech Project Manager will circulate copies of the client statement of work to the project team, including the QA Officer and key personnel, for their input on staffing, QA requirements, and logistical issues identified in the statement of work.

2. Data Check-In:

    a. *Input Data Integrity*: Data are spot-checked to detect potential data entry errors. In addition, Tetra Tech may use a customized user input interface that performs certain appropriate checks on data as they are being manually entered when a project involves the input of large quantities of data, thereby reducing the potential for incorrect data entry. In any project with automated processing it is important to visually inspect the GIS data to check for adherence to database design, attribute accuracy, logical consistency and referential integrity.

    b. *Assessments of Processed Data*: The ability of a desktop geospatial product to accurately characterize the conditions in the project area are dependent on the quality of data entering the process and imported into a GIS. QC procedures are implemented during data processing activities, and technical reviews of processed data are conducted by qualified personnel. Tetra Tech follows guidance on data management, information security, record management, and data processing provided or referenced by the client, including *Data Standards* (EPA CIO 2133.0), *Information Resources Management Policy Manual* (EPA CIO 2100.0), *Records Management Manual* (EPA CIO 2155.0), and *Records Management Policy* (EPA CIO 2155.1) available on the Internet at http://www.epa.gov/irmpoli8.

3. Automation Plan: Large data sets require automated processes to ensure efficiency and accuracy. Macros can be a way to automate multiple processes in sequence. When using a macro in a database-related software, the macro must be coded in a way that the result can be independently followed and replicated. In these cases it is important to be able to trace an error back to the step it was introduced.

    For GIS related processes, Earth Systems Research Institute's (ESRI's) ModelBuilder tool can help do the same task by linking multistep processes together and producing a visual flow diagram to track automated processing. In any project with automated processing it is important to visually inspect the GIS data to check for adherence to database design, attribute accuracy, logical consistency and referential integrity. Any visual inspection will be coupled with automated QA to ensure formulas and GIS algorithms have worked to their desired effect.

4. Data Organization: All information that is received by the project will be tracked and maintained from the moment of receipt, even though it may not be used in the final products for various reasons. Submitted and retrieved information, including suggested data sources and citations, will be immediately recorded to allow traceability throughout the entire lifecycle. Collected data will be stored via a directory structure that will allow Tetra Tech to work on and analyze copies of the data, while preserving the original versions. This will be accomplished by creating a 'RAW' and 'WORKING' directory structure that Tetra Tech has successfully used in the past.

   Throughout the actual GIS data processing, analysis, and layout, a GIS practitioner will generate many versions of a shapefile. This includes all the edits needed to suit the particular function of the project. The final shapefiles folder will contain the final version after edits of all the shapefiles, including those that were used to create map figures. A "Test_Shapefile" folder may house all the separate versions of shapefiles. This includes all the spatial joins, clips, projections, or anything else that was not used in the final product. Additionally, a "Draft_Shapefile" folder may house edited versions that needed to be updated with more current data and shapefiles that were used for a portion of the project but not the final output.

5. Product Review: Tetra Tech will document the data collected in the final report of each project, as well as, a description of all QC activities and analyses where data analysis assumptions or procedures were not obvious. Summary statistics and discussion will include the following:

   - Quality of secondary data (requirements will be determined in consultation with the client).
   - Accuracy of extraction/interpretation of pertinent data from secondary data sources for use in deliverables.
   - 10 percent of extractions/interpretations will be checked (100 percent of discrepancies will be resolved).
   - Accuracy of data transfers will be checked. The Tetra Tech QC Officer will independently check transferred data using a standard-level review, consisting of independently checking each different file type (i.e., a file with different structure or legacy), and confirming that the first, last, and a selected middle portion of the data were transferred correctly. More files (up to 10 percent) will be reviewed if files are processed individually, while fewer checks (no less than 2 data files of each type) will be used for automated to semi-automated procedures. All identified data processing errors will be corrected and the Tetra Tech QC Officer will perform a follow-up review of the correct components to ensure that the errors have been corrected.

- Hand-entered data will be checked (100 percent of discrepancies will be resolved).
- Accuracy of data conversions, including reformatting, will be checked. The Tetra Tech QC Officer or his or her designee will perform up to 10 percent independent recalculations of computations (including conversions) and graphs, but no less than two examples of each type of computation and two examples of each graphic type. More calculations (up to 10 percent) will be reviewed if data sets or points are processed individually while fewer checks (no less than two examples of each type of computation and two examples of each graphic type) are appropriate for automated to semi-automated procedures. All identified data calculation errors will be corrected and the Tetra Tech QC Officer or his designee will perform a follow-up review of the corrected components to ensure that the errors have been corrected.

6. Data Management: Most work that Tetra Tech conducts involves acquiring and processing data, and generating reports and documents, all of which require the maintenance of computer resources. Tetra Tech's computers are either covered by on-site service agreements or serviced by in-house specialists. When a problem with a microcomputer occurs, in-house computer specialists diagnose the trouble and correct it if possible.

   When outside assistance is necessary, the computer specialists will call the appropriate vendor. For other computer equipment requiring outside repair and not covered by a service contract, local computer service companies are used on a time-and-materials basis. Routine maintenance of microcomputers is performed by in-house computer specialists. Electric power to each microcomputer flows through a surge suppressor to protect electronic components from potentially damaging voltage spikes. Employees who keep important data on their personal desktop or laptop computers are given backup drives. These drives are set to conduct automatic backups of key data. Employees also receive instructions on how to manually back up key files. Tetra Tech's network servers are backed up daily. Copies of the backed-up data are kept off-site. On request or as needed, Tetra Tech archives and documents data for easy restoration. Automated screening systems have been placed on all Tetra Tech systems and are updated regularly to ensure that viruses are identified and destroyed. Annual maintenance of software is performed to keep up with evolutionary changes in computer storage, media, and programs.

7. Data Transfer/Transmittal: Data that are transferred among databases will be checked for completeness at the time of transfer by enumerating the numbers of records in the original and final data sets. Data transfers will be tagged with upload dates and times to accommodate completeness reviews. If data transfer is incomplete, the missing records will be sought and transferred individually if they are valid. A second round of completeness checks will ensue after successive transfers. Once data sets are compiled, the complete set of data value distributions will be analyzed to identify outliers that may result from data entry errors or erroneous unit conversions. Outliers will be identified and

resolved. Valid outliers can occur and will not be eliminated if the experienced analyst thinks they are plausible. Outliers that are not plausible or show a pattern of potential error will be brought to the attention of the original data supplier (if possible) and will be excluded from analysis until the original data supplier can confirm their validity.

The accuracy of the transfer of data from electronic databases to the project database(s) will be determined by checking whether data from the original database have been transferred to appropriate rows and columns, whether the same number of decimal places after the decimal point in the original database has been used, and whether the same units from the original database have been used. The Tetra Tech QC Officer will independently check transferred data using a standard-level review, consisting of independently checking each different file type (i.e., a file with different structure or legacy), confirming the first, last, and a selected middle portion of the data were transferred correctly. More files (up to 10 percent) will be reviewed if files are processed individually while fewer checks (no less than two data files of each type) will be used for automated to semi- automated procedures. This procedure will aid the evaluation process by improving consistency in data transfers.

Spatial data such as shapefiles and model input files are often composed of a family of files that need to be stored together to function. When transferring spatial data, consider that all of these files should be transferred together and that project files such as .mxds will need to be relinked after the files have been moved. Geodatabases are also available, and they are becoming more common for storing multiple spatial data sets for a project while maintaining data set relationships, behaviors, annotations, and metadata.

Data generated within a GIS platform will likely be too large to deliver over email. In these cases setting up an FTP site may be necessary. Ensuring the file size that is in the product posted to the FTP size is the same size as the project downloaded by the end user is a good way to ensure all data has been successfully transmitted.

8. Data Projections: All spatial data should have the same coordinate system for comparison; therefore, transformations are often necessary. Coordinate systems include both a geodetic datum and a projection type. A geodetic datum describes the model that was used to match the location of features on the earth's surface to coordinates on the map. Common datums include the World Geodetic System 1984 (WGS84) for a good representation for the world as a whole and the North American Datum 1983 (NAD83) or 1927 (NAD27) for a representation for North America. A projection type (e.g., the Universal Transverse Mercator [UTM] or state plane) is a visual representation of the earth's curved surface on a flat computer screen or paper. Often, if available, a state plane coordinate system or other state system is the most accurate system for a particular project area. Spatial data sets can be in the same projection but be referenced to different datums and therefore have different coordinate values (e.g., latitude and longitude or UTM). To fully represent a location spatially and avoid errors or confusion, coordinates are needed along with the datum. The difference between WGS84 and NAD83 is basically negligible (about 1 meter); however, the difference between NAD27 and

NAD83 (and WGS 1984) varies from about 10 meters in the Great Lakes area to 100 meters on the west coast and up to 400 meters in Hawaii. NAD27 is still used as the basis for most USGS topographic maps, but NAD83 was created to provide a more accurate representation of the earth's ellipsoid shape. By default, most GPS units export points in WGS84, but settings can be changed to display points using different systems. Significant error can be introduced when data with different or unknown datums are introduced, including errors in distance or area measurement and errors in relating the spatial location of features between data sets. GIS software or mathematical algorithms allow for the conversion of spatial data from one coordinate system to another.

9. Storage and Archives: Data storage involves keeping the data in such a way that they are not degraded or compromised and that any datum desired can be retrieved. At every stage of data processing at which a permanent collection of data is stored, a separate copy is maintained for purposes of integrity and security. Data are securely archived in a suitable manner. Aspects such as storage media, conditions, location, access by authorized personnel, and retention time are addressed in consultation with the client. Before archiving, the Tetra Tech Project Manager ensures that all data sets are complete, with all of the client-required data standards honored.

   Tetra Tech will store all computer files associated with the project in a project subdirectory (subject to regular system backups). Tetra Tech will maintain version control of draft and final deliverables by indicating the preparation date or revision number in the file name. The length of archival will be decided upon consultation with Client specifications.

10. Training Requirements: Project statements of work or work plans and quality assurance documents will be distributed to all project participants for review and reference. All relevant project personnel will have expertise in collecting and evaluating and analyzing GIS data. In addition, all relevant project personnel will have working knowledge of any additional software necessary to complete the project requirements.

   GIS Analysts should have access to ArcGIS software no earlier than version 10.0 for file compatibility purposes. All project personnel will have expertise in environmental sciences, as well as knowledge of the quality system for the project and this knowledge and expertise will be enumerated in project documentation.

Pertinent QA and QC Procedures

1. Spatial Data QA/QC: There are many considerations for spatial data QA/QC that must be adapted for each geospatial project. These considerations include the following, which were adapted from the ESRI GIS software developer:

   - GIS data completeness, consistency, accuracy, and resolution (including projection).
   - Identifying errors visually in ArcMap.

- Creating methods (data workflow) for project processes, including QC workflow for associated processes.
- Noting and tracking data errors either within attribute table fields or in associated project documentation.
- Checking schema (names, fields, and coordinate systems); checking attributes (missing or bad values).
- Visual review techniques: performing visual QC; setting symbols and labels; and labeling techniques for points, lines, and polygons.

The Tetra Tech Project Manager will determine in consultation with the client Project Manager how spatial data QA/QC will be implemented for a particular project.

2. <u>Attribute Data QA/QC</u>: All geospatial data (shapefiles) downloaded from publicly available online data sources will have associated attribute data contained within their respective database files. These attribute data quantify and occasionally narratively describe the spatial data within tabular fields. These data should be evaluated under the same measurement performance criteria that traditional data sources (spreadsheets and databases) are evaluated.

   Measurement performance criteria that will be used for data handling for any given project will include accuracy and completeness. Tetra Tech will also evaluate GIS metadata against the Federal Geographic Data Committee (FGDC) metadata standard to determine whether the GIS data are suitable for use for a given project. Tetra Tech will provide a description of the data evaluation factors and limits (as determined in consultation with the client) in the report of data collected. Whenever possible, data will be downloaded electronically from various electronic sources to reduce scanning of hard copy data.

3. <u>Metadata QA/QC</u>: Many projects will rely on secondary data. Geospatial metadata is used throughout the project lifecycle. All personnel that download geospatial secondary data become Metadata Stewards.

   Tetra Tech Metadata Stewards will evaluate GIS metadata against the FGDC (<u>www.fgdc.gov</u>) metadata standard to determine whether the GIS data are suitable for use for any given project. The FGDC has developed a metadata standard for geospatial data generated for and by all federal agencies which all federal agencies are to follow according to Executive Order 12906, *Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure*. Detailed metadata indicating the source, scale, resolution, accuracy, and completeness provide a basis to assess the adequacy of existing data for use per EPA Order 5360.1 A2, *Policy and Program Requirements for the Mandatory Agency-wide Quality System*.

If requested by the client through written technical direction, additional GIS QA/QC requirements can be addressed; examples include:

a. Full FGDC compliant metadata in XML format.
    i. Use the appropriate metadata profile described in the FGDC Content Standard for Digital Geospatial Metadata (CSDGM), such as Biological Profile, Shoreline Profile, and Remote Sensing Profile. Metadata profiles can be obtained from http://www.fgdc.gov/metadata.
b. A single file represents the entire data set (layer).
c. Each field that is mandatory and/or applicable must be described in the metadata.
d. The EPA Metadata Editor (EME) is used to create metadata (https://edg.epa.gov/EME/) and export to XML if using ESRI software.
e. Secondary data is accompanied by a metadata validation file. If a metadata validation file does not exist, metadata validation is performed prior to including the data set in the project. This is to ensure and document that the data set meets the needs of the intended use.
f. Where possible, extramural organizations are encouraged to use the EME. This facilitates subsequent review, collation, and verification of metadata validation.
g. The appropriate Geospatial Accuracy Tier noted in Appendix A of the EPA National Geospatial Data Policy is included as Supplemental Information. This facilitates collation of data and information related to scale.
h. Where practical, transition to the ISO 19115 metadata standards (North American Profile) is encouraged. At this moment, ISO metadata is optional.

4. Version Control: Data can be managed in a number of different platforms. GIS versioning can be managed through ESRI's ArcCatalog via folder and file naming conventions. Date of creation, ArcMap processing tool, and project name should all be reflected in the file name. Including spaces and non-traditional characters in file names is required for GIS processing and management.

Appendix D. National Risk Management Research Laboratory (NRMRL) QAPP Requirements for Research Model Development and Application Projects (10/2008)[1]

General Requirements: Include cover page, distribution list, approvals, and page numbers.

1. COVER PAGE (MODEL DEVELOPMENT AND MODEL APPLICATION)

   Include the Division/Branch, project title, revision number, EPA technical lead, QA category, organization responsible for QAPP preparation, and date.

2. PROJECT DESCRIPTION AND OBJECTIVES (MODEL DEVELOPMENT AND MODEL APPLICATION)

   In this document, "project" can mean (a) development or substantial modification of a model for application to address a general problem; (b) application of an existing model (including minor modification to the existing model) to address a specific problem; or (c) a development or substantial modification and application of a model to address a specific problem.

   2.1. State the purpose of the project and list the project objective(s). Indicate whether a new model will be developed, or an existing model will be used.

   2.2. Describe the problem, the data to be generated by the model, how the data will be used to address the problem, and the intended users of the data. Describe the environmental system/setting to be modeled, where the model will be applied, and the circumstances and scenarios to be considered for the modeled system.

3. ORGANIZATION AND RESPONSIBILITIES (MODEL DEVELOPMENT AND MODEL APPLICATION)

   3.1. Identify all project personnel, including QA, and related responsibilities for each participating organization, as well as their relationship to other project participants.

   3.2. Include a project schedule that includes key milestones.

4. MODEL SELECTION (MODEL APPLICATION ONLY)

   4.1. Discuss model selection with respect to how it will be used and how it is consistent with the project objectives. Include fundamental details such as whether the model will be used to predict the world beyond the model or in scenario analysis of the model itself. Describe the limits to where the model is applicable.

   4.2. Provide a description of the model attributes/capabilities required for the project. This description should include hardware requirements and restrictions. Provide an overview of the candidate model attributes.

      Model origin and its original purpose, if applicable

      Model structure (e.g., stochastic vs. deterministic, structural framework)

      Parameters and variables

[1] http://www.epa.gov/nrmrl/qa/pdf/ResearchModelDevandAppQAPPNRMRLrev0.pdf

The algorithms and equations that have been developed to support the model theory, along with the sources of the algorithms

Spatial extent (individual, group, population)

Spatial resolution (location independent/dependent, dimensionality)

Temporal extent (length of modeling period)

Temporal resolution (time step)

4.3. Identify the model to be used or, if the model has not yet been selected, describe the process to be used or the selection of an existing model.

4.4. Identify specific requirements for application of the selected model for this specific purpose (e.g., current and appropriate data, parameter values, assumptions).

4. MODEL DESIGN (MODEL DEVELOPMENT ONLY)

4.1. Describe the conceptual model(s) for the system, including model parameters.

4.2. Identify algorithms and equations that have been developed to support the model theory, or if such equations are not already available, describe the process used to develop these equations.

4.3. Specify required sources for model databases and any requirements for these data (e.g., quality, quantity, spatial, and temporal applicability). If data sources are not currently known, describe the criteria used to identify sources. Describe how any data gaps will be filled.

5. MODEL CODING (MODEL DEVELOPMENT ONLY)

5.1. Discuss the requirements for model code development, where applicable.

5.2. Identify computer hardware and software requirements.

5.3. Discuss requirements for code verification.

6. MODEL CALIBRATION (MODEL DEVELOPMENT AND MODEL APPLICATION)

Calibration is the process of adjusting model parameters within physically defensible ranges until the resulting predictions give the best possible or desired degree of fit to the observed data. Calibration should be applied each time the model is modified.

6.1. Discuss how the model will be calibrated.

6.2. Identify the type and source of data (e.g., new data, existing data, professional judgment, expert opinion elicitation) that will be used to calibrate the model, including any requirements for the data (quality, quantity, and spatial and temporal applicability). If data sources are not currently known, describe the criteria used to identify sources.

6.3. Specify acceptance criteria which need to be met for the difference between predicted and observed data during model calibration, where applicable. The statistical methods (e.g., goodness-of-fit, regression analysis) or expert judgment to be used should also be discussed.

7. MODEL VERIFICATION (MODEL DEVELOPMENT AND MODEL APPLICATION)

Verification consists of comparing the predictions of a calibrated model with available data that were not used in the model development and calibration.

7.1. Discuss the approach to be used for model verification. Describe how the verification is appropriate based on the model's purpose. Identify the type and source of data (e.g., new data, existing data, synthetic test data sets, professional judgment, expert opinion elicitation) that will be used to verify the model. If data sources are not currently known, describe the criteria used to identify sources.

7.2. Discuss the characterization of model uncertainty (model framework, model input, and model applicability) and sensitivity (model application only).

7.3. Describe any requirements (quality, quantity, and spatial and temporal applicability) for the data that will be used to verify the model.

7.4. Describe the approach used to determine if the independent data verify the model predictions. Specify the criteria which need to be met for the difference between predicted and observed data for the model to be considered to be verified. Discuss any statistical methods to be used (e.g., goodness-of-fit, regression analysis).

8. MODEL EVALUATION (MODEL DEVELOPMENT AND MODEL APPLICATION)

8.1. List and describe the qualitative or quantitative assessment process to be used to generate information to determine whether a model and its analytical results are of a quality sufficient for the intended use.

8.2. List and describe any independent/external evaluation and review of the model and model design, such as scientific peer review.

9. MODEL DOCUMENTATION (MODEL DEVELOPMENT AND MODEL APPLICATION)

Specify the requirements for model documentation. Good documentation includes:

Final model description, final model specifications (model development only), hardware and software requirements, including programming language, model portability, memory requirements, required hardware/software for application, data standards for information storage and retrieval

The equations on which the model is based (model development only)

The underlying assumptions

Flow charts (model development only)

Description of routines (model development only)

Data base description

Source code (model development only)

Error messages (model development only)

Parameter values and sources

Restrictions on model application, including assumptions, parameter values and sources, boundary and initial conditions, validation/calibration of the model, output and interpretation of model runs (model development only)

The boundary conditions used in the model

Limiting conditions on model applications, detail where the model is or is not suited

Changes and verification of changes made in code

Actual input data (type and format) used

Overview of the immediate (non-manipulated or –post processed) results of the model runs (model application only)

Output of model runs and interpretation

User's guide (electronic or paper)

Instructions for preparing data files (model development only)

Example problems complete with input and output

Programmer's instructions

Computer operator's instructions

A report of the model calibration, validation, and evaluation (model development only)

Documentation of significant changes to the model

Procedures for maintenance and user support, if applicable

10. REPORTING (MODEL DEVELOPMENT AND MODEL APPLICATION)
11. List and describe the deliverables expected from each project participant.
12. Specify the expected final product(s) that will be prepared for the project (e.g., journal article, final report).
13. REFERENCES

Provide the references either in the body of the text as footnotes or in a separate section.

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. CONTRACT ID CODE		PAGE OF PAGES 1 2	
2. AMENDMENT/MODIFICATION NO. P00001	3. EFFECTIVE DATE See Block 16C	4. REQUISITION/PURCHASE REQ. NO. PR-OW-20-00227	5. PROJECT NO. *(If applicable)*
6. ISSUED BY CODE CAD		7. ADMINISTERED BY *(If other than Item 6)* CODE	

6. ISSUED BY
CAD
US Environmental Protection Agency
26 West Martin Luther King Drive
Mail Code: W136
Cincinnati OH 45268-0001

8. NAME AND ADDRESS OF CONTRACTOR *(No., street, county, State and ZIP Code)*
TETRA TECH, INC.
Attn: George Townsend
10306 EATON PL STE 340
FAIRFAX VA 22030

CODE 198549560 | FACILITY CODE

(x) 9A. AMENDMENT OF SOLICITATION NO.

9B. DATED *(SEE ITEM 11)*

x 10A. MODIFICATION OF CONTRACT/ORDER NO.
EP-C-17-031
68HERC20F0051

10B. DATED *(SEE ITEM 13)*
11/14/2019

11. THIS ITEM ONLY APPLIES TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in Item 14. The hour and date specified for receipt of Offers ☐ is extended. ☐ is not extended.
Offers must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation or as amended , by one of the following methods: (a) By completing Items 8 and 15, and returning ________ copies of the amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted ; or (c) By separate letter or electronic communication which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGEMENT TO BE RECEIVED AT THE PLACE DESIGNATED FOR THE RECEIPT OF OFFERS PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If by virtue of this amendment you desire to change an offer already submitted , such change may be made by letter or electronic communication, provided each letter or electronic communication makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

12. ACCOUNTING AND APPROPRIATION DATA *(If required)*
See Schedule

13. THIS ITEM ONLY APPLIES TO MODIFICATION OF CONTRACTS/ORDERS. IT MODIFIES THE CONTRACT/ORDER NO. AS DESCRIBED IN ITEM 14.

CHECK ONE	
	A. THIS CHANGE ORDER IS ISSUED PURSUANT TO: *(Specify authority)* THE CHANGES SET FORTH IN ITEM 14 ARE MADE IN THE CONTRACT ORDER NO. IN ITEM 10A.
	B. THE ABOVE NUMBERED CONTRACT/ORDER IS MODIFIED TO REFLECT THE ADMINISTRATIVE CHANGES *(such as changes in paying office, appropriation data, etc.)* SET FORTH IN ITEM 14, PURSUANT TO THE AUTHORITY OF FAR 43.103(b).
	C. THIS SUPPLEMENTAL AGREEMENT IS ENTERED INTO PURSUANT TO AUTHORITY OF:
X	D. OTHER *(Specify type of modification and authority)* BILATERAL AGREEMENT - NO COST NO POP EXTENSION PWS AMENDMENT

E. IMPORTANT: Contractor ☐ is not ☒ is required to sign this document and return 1 copies to the issuing office.

14. DESCRIPTION OF AMENDMENT/MODIFICATION *(Organized by UCF section headings, including solicitation/contract subject matter where feasible.)*

DUNS Number: 198549560
TOCOR: Susan Jackson Max Expire Date: 11/13/2020
LIST OF CHANGES:
Reason for Modification: Other Administrative Action - Bilateral Agreement for No Cost No PoP Extension - PWS Amendment (See Attached)

Continued ...

Except as provided herein, all terms and conditions of the document referenced in Item 9 A or 10A, as heretofore changed, remains unchanged and in full force and effect.

15A. NAME AND TITLE OF SIGNER *(Type or print)*		16A. NAME AND TITLE OF CONTRACTING OFFICER *(Type or print)* Andrea Dehne	
15B. CONTRACTOR/OFFEROR (Signature of person authorized to sign)	15C. DATE SIGNED	16B. UNITED STATES OF AMERICA ELECTRONIC SIGNATURE (Signature of Contracting Officer)	16C. DATE SIGNED 03/03/2020

CONTINUATION SHEET	REFERENCE NO. OF DOCUMENT BEING CONTINUED EP-C-17-031/68HERC20F0051/P00001	PAGE 2 OF 2

NAME OF OFFEROR OR CONTRACTOR
TETRA TECH, INC.

ITEM NO. (A)	SUPPLIES/SERVICES (B)	QUANTITY (C)	UNIT (D)	UNIT PRICE (E)	AMOUNT (F)
	Payment: RTP Finance Center US Environmental Protection Agency RTP-Finance Center (AA216-01) 109 TW Alexander Drive www2.epa.gov/financial/contracts Durham NC 27711 Period of Performance: 11/15/2019 to 11/13/2020 Delivery-Invoice Payment Schedule shall not exceed a frequency greater than once a month and 90% of the task order price. Acceptance for invoicing is based on deliverable approval by the TOCOR. For efficient processing IAW FAR clause 52.232-32, performance based payment invoicing amounts will not be submitted until the TOCOR provides deliverable approval. The TOCOR will notify Tetra Tech within 14 days of submission of a deliverable of EPAs intention to approve or disapprove. TOCOR: Susan Jackson/(202)566-1112/jackson.susank@epa.gov ALTOCOR: Janice Alers-Garcia/(202)566-0756/alers-garcia.janice@epa.gov				

PERFORMANCE WORK STATEMENT PR-OW-19-00566
Contract #EP-C-17-031
TASK ORDER #68HERC20F0051/SOL#68HERC19R0081

Amendment 1

I. Title: Development of Biological Indicators and Criteria, Methods and Assessment Integration

II. Period of Performance: November 15, 2019 to November 13, 2020

III. Task Order Contracting Officer Representative (TOCOR):

Susan Jackson
Health and Ecological Criteria Division
Office of Water, Office of Science and Technology
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue (4304T)
Washington, DC 20460
Tel: (202)566-1112, Fax: (202)566-1140
jackson.susank@epa.gov

Alternate TOCOR:

Janice Alers-Garcia
Tel: (202) 566-0756, Fax: (202)566-1140
alers-Garcia.janice@epa.gov

IV. Background Information:

The Clean Water Act (CWA) directs EPA to restore and maintain the biological integrity of the Nation's waters. Under the CWA, the EPA has established a Water Quality Standards (WQS) Program to help achieve this objective. Biological criteria, developed using biological assessments and other ecological assessment data, are a component of a WQS and can be used to support overall water quality management (WQM) program information needs. The EPA is developing methods and tools to support incorporation of biological and other ecological assessment data into EPA, state, territorial, tribal and county (herein defined as "state") WQM programs, including developing, evaluating and implementing assessment approaches using biological, chemical and physical data; developing and testing user friendly databases; query, data visualization and database management approaches and tools; reviewing and synthesizing of existing data, methods and literature to efficiently build on an established body of scientific research and practice; and evaluating the statistical robustness of technical methods and approaches for assessments and model prediction. To develop effective methods and support for states, communication and engagement is fundamental in the planning, development and transfer of results.

If needed for purposes of technical clarification, use of technical collaboration will be in writing and sent to the Contracting Officer and the Task Order Contract-Level COR.

V. Objectives

This task order (TO) is to support the development of a Biological Condition Gradient (BCG) for Streams and Wadeable Rivers in the Pacific Northwest Maritime Region (See Task 2); finalize the numeric BCG framework and decision rules for coral reef ecosystems using benthic and fish assemblage data and information (See Task 3); and provide technical support to states through informal technical consultations (See Task 4).

VI. Quality Assurance (Contract PWS Section 5)

The contractor shall address the QA requirements of this TO through a combination of the following: 1) Tetra Tech SOP for Statistical Analyses (Appendix A, March 2017), 2) Tetra Tech SOP for Secondary Data Management (Appendix B, March 2017), and 3) Tetra Tech SOP for Geospatial and Data Management (Appendix C, March 2017) which document how quality assurance and quality control will be applied to the collection and use of existing environmental data and/or survey information for this TO. The contractor shall discuss with the EPA TOCOR if any of the specific TO tasks are not readily covered under the approved SOPs. If not readily covered under the approved SOPs then a supplement QAPP shall be developed if needed.

Any project specific quality assurance issues shall be reported in the monthly progress reports as specified under Subtask 1. The contractor shall document relevant QA activities in any deliverable. All QA documentation prepared under the TO shall be considered non-proprietary. The contractor shall provide a signed review sheet (in the front of the SOPs/QAPPs) indicating the SOPs/QAPPs have been read and shall be followed by all personnel participating in this TO.

The contractor shall submit relevant QA documentation as requested by the EPA TOCOR. The contractor shall permit a QA review of data entry documents and procedures by an authorized agent of EPA at any time during the performance period (given advanced notification).

Task 2 Develop Biological Condition Gradient (BCG) for Streams and Wadeable Rivers in the Pacific Northwest Maritime Region and Task 3 Develop numeric BCG framework and decision rules for coral reef ecosystems using benthic macroinvertebrate communities and fish assemblage data and information support development of a first-generation numeric model. The contractor shall fulfill the requirements described in National Risk Management Research Laboratory (NRMRL) QAPP Requirements for Research Model Development and Application Projects (10/2008) for applicable areas of Task 2 and 3. The NRMRL QAPP requirements are included in Appendix D of this TO.

Information Quality Guidelines & Information Quality Review

The contractor shall ensure the products developed under this TO comply with EPA's Quality System and other related QA policies, and the Office of Water's Quality Management Plan. The contractor shall ensure that the information in the products meets the standards of "Objectivity", "Integrity", "Utility", "Reproducibility" and "Transparency" as described in the OW Information Quality Guideline (IQG) for each deliverable from this TO as they may be used in Agency decision-making and/or will be publicly available documents. If requested by the EPA TOCOR via written technical collaboration, the contractor shall provide a memorandum describing how the planned product(s) developed meet EPA's & OW's Information Quality Guidelines. As part of that memo, the contractor shall document the quality assurance procedures used in developing the deliverables under this TO. The contractor shall provide the memo at the time it delivers the Final Summary Report. As directed by the EPA TOCOR via written technical collaboration, the contractor shall meet with the EPA TOCOR (through teleconference) to discuss the Guidelines and the contractor's role in completing the memo and OW IQG checklist.

VII. Scope of Work

Task 1: Communication, Prepare Monthly Progress and Financial Reports, Coordination and Notification

SubTask 1.1: Communication/Kickoff Call
The Contractor shall contact the EPA TOCOR and schedule a kickoff project meeting.

SubTask 1.2: Communication and development of a regular reporting schedule
The Contractor shall establish communication with the EPA TOCOR and develop a regular reporting schedule throughout the period of the TO.

SubTask 1.3: Monthly Progress and Financial Reports
Submit and prepare monthly progress and financial reports in accordance. The monthly progress report shall include project status, expenditures to date, unexpected problems or concerns, corrective actions, lessons learned, QA/QC activities, and next steps.

SubTask 1.4: Coordination and notification
This task requires coordination with other organizations and therefore it is particularly important that the Contractor shall notify the EPA TOCOR of issues, problems, questions, or delays as soon as they become apparent or if they are anticipated.

Task 1. Deliverables

Task	SubTasks	Deliverable	Due
1	1.1	Communication/Kick-off call	Within 3 days of TO Award
1	1.2	Regular reporting schedule	As requested by the EPA TOCOR
1	1.3	Progress and financial reports	Monthly
1	1.4	Coordination and notifications	Immediately upon knowledge of incident

Task 2: Develop Biological Condition Gradient (BCG) for Streams and Wadeable Rivers in the Pacific Northwest Maritime Region (Contract PWS Section 2, Task Areas 2, 3, 4, 5, 6, 7)

The contractor shall provide technical support to calibrate the BCG for streams in the Pacific Northwest Maritime Region (CONUS). The contractor shall use existing data sets that have documented QA/QC review including but not limited to: Washington and Oregon state biological monitoring datasets (publicly accessible), EPA's StreamCat data (Hill et al. 2016), Indices of

Catchment and Watershed Integrity (ICI and IWI, respectively) (USEPA website, publicly accessible) and NorWeST Summer Stream Temperature Model data (Isaak et al. 2017).

SubTask 2.1*: *Develop a Taxa Tolerance Database for the Maritime Pacific region

2.1.a. Conduct tolerance analyses using the IWI scores, the NorWeST summer stream temperature metrics and up to four StreamCat variables (such as percent urban and percent agricultural land use).

2.1.b. Format analysis results as a taxa tolerance database in a MS Access database.

2.1.c. Document scientific basis and process to clearly illustrate how the results were derived and the ecological basis for this results.

SubTask 2.2*: *Develop BCG taxa attribute assignments based on taxa tolerance database (upon finalization of SubTask 2.1)

2.2.a. Assign attribute categories to the taxa listed in the data sets used to develop the taxa tolerance database.

2.2.b. Facilitate a webinar with the data providers and state and county bioassessment program scientists to explain the BCG attribute assignments and to solicit their feedback.

2.2.c. Revise attribute assignments based on comments from data providers and state and country bioassessment program scientists.

SubTask 2.3*: *Develop site assignment worksheets and supporting technical material for BCG development webinar using procedure defined in "A Practitioner's Guide to the Biological Condition Gradient: A Framework to Describe Incremental Change in Aquatic Ecosystems" (EPA-842-R-16-001)

SubTask 2.4*: *Develop Numeric BCG for streams in the Pacific Northwest Maritime Region

2.4.a. Facilitate 2 to 3 webinars with data providers, state and county bioassessment program scientists and 2 – 3 expert taxonomists using the site assignment worksheets (subtask 2.3)). The objective of the webinars is to develop decision rules for assigning sites to BCG levels using procedure defined in "*A Practitioner's Guide to the Biological Condition Gradient: A Framework to Describe Incremental Change in Aquatic Ecosystems" (EPA-842-R-16-001).*

2.4.b. Based on outcome of webinars, develop numeric BCG for streams in Pacific Northwest Maritime Region (CONUS).

2.4.c. Prepare technical report that documents method, rationale and process for development of numeric BCGs for fish and benthic macroinvertebrates in the Caribbean and for the screening method.

2.4.d. Revise technical report per comments received from EPA TOCOR.

Task 2. Deliverables

Task	SubTask	Deliverable	Due
2	2.1.a-c.	Taxa Tolerance Database	Two weeks after receiving final comments from the EPA TOCOR
2	2.2. a-c	BCG taxa assignments	Two weeks after receiving final comments from the EPA TOCOR
2	2.3	Site Assignment Worksheets	Two weeks after receiving final comments from the EPA TOCOR
2	2.4.a-d	Numeric BCG and Technical Report	Two weeks after receiving final comments from the EPA TOCOR

Task 3: Develop numeric BCG framework and decision rules for coral reef ecosystems using benthic macroinvertebrate communities and fish assemblage data and information. (Contract PWS Section 2, Task Areas 2, 3, 4, 5, 6, 7).

The contractor shall provide technical support to develop numeric BCG models for assigning individual sample sites to biological condition levels for coral reef fish and benthic macroinvertebrate communities in the Caribbean. The contractor shall use existing data sets with QA/QC documentation from the United States Virgin Islands (USVI) and Puerto Rico (PR) territorial monitoring programs and from the National Oceanographic and Atmospheric Administration (NOAA) Coral Reef Monitoring and Marine Sanctuary Programs. The US EPA TOCOR will coordinate with the contractor to ensure that the correct datasets with documented QA/QC review are accessed. An expert panel met in March 2019, to review a model prototype and provide expert comments and recommendations on the prototype. The US EPA TOCOR will provide to the contractor the prototype, summary of the meeting, key findings and recommendations.

SubTask 3.1: Develop final numeric BCG for coral reef fish community in the Caribbean

3.1.a. Revise prototype fish model to address expert comments and recommendations.

3.1.b. Using data from USVI, PR and NOAA, test application of revised BCG.

3.1.c. Prepare validation samples for rating by the data providers and scientists.

3.1.d. Conduct webinars with data providers and territorial and federal coral monitoring program scientists to discuss model performance and to test model revision (model validation).

3.1.e. Finalize fish model based on validation results.

SubTask 3.2: Develop final numeric BCG for coral reef benthic macroinvertebrate community in the Caribbean

3.2.a. Revise prototype benthic macroinvertebrate BCG to address expert comments and recommendations.

3.2.b. Using data from USVI, PR and NOAA, test application of revised BCG.

3.2.c. Prepare validation samples for rating by the data providers and scientists.

3.2.d. Conduct webinars with data providers and territorial and federal coral monitoring program scientists to discuss model performance and to test model revision (model validation).

3.2.e. Finalize benthic macroinvertebrate BCG based on validation results.

SubTask 3.3: Develop assessment screening metrics for both fish and benthic macroinvertebrate BCGS

3.3.a. Test both assemblage BCGs for a subset of metrics to use individually or in combination as a screening method to determine if a coral reef is supporting or not supporting aquatic life. The screening tool will be used as an indicator that a site at risk for not supporting aquatic life and more intensive monitoring required.

3.3.b. Present results of analysis to the EPA TOCOR, USVI and PR bioassessment program scientists and facilitate discussion on selection of metrics that meet each of their program requirements.

3.3.c. Revise as needed the assessment screening method to address comments from the EPA TOCOR, USVI and PR bioassessment program scientists.

SubTask 3.4: Technical Documentation

3.4.a. Prepare technical report that documents method, rationale and process for development of numeric BCGs for fish and benthic macroinvertebrates in the Caribbean and for the screening method.

3.4.b. Revise technical report per comments received from TOCOR.

Task 3. Deliverables

Task	**SubTask**	**Deliverable**	**Due**
3	3.1.a-d	Numeric Fish BCG	Two (2) weeks after receiving final comments from the EPA TOCOR
3	3.2.a-e	Numeric Benthic Macroinvertebrate BCG	Two (2) weeks after receiving final comments from the EPA TOCOR
3	3.3.a-c	Screening Method	Two (2) weeks after receiving final comments from the EPA TOCOR
3	3.4.a-b	Technical Documentation	Two (2) weeks after receiving final comments from the EPA TOCOR

Task 4: Technical ~~Consultations~~ Projects (Contract PWS Section 2, Task Areas 2, 3, 4, 5,6, 7)

The contractor shall provide technical support to states ~~through informal technical consultations with US EPA. These activities will be~~ in the form of technical projects, that will be identified to the contractor by the EPA TOCOR via email, teleconference, or web conference. **All work is within the original anticipated scope of the PWS and project hours were proposed, evaluated, and approved by the EPA TOCOR. The technical projects listed under Task 4; SubTasks 4.5 and 4.6, simply refine and spell out the project(s) associated with the original hours proposed for technical support. This refinement and resulting task order modification formalizes both parties' agreement to a no cost, no period of performance extension.** The type of technical project ~~These consultations~~ may include, but ~~are~~ is not limited to:

- Exchanging scientific literature,
- Reviewing and providing scientific feedback on a state's field sampling design, analytical methods, and data analysis design;
- The construction and interpretation of ecological models (empirical, numerical),
- Exploring assessment endpoints and conceptual models related to aquatic life, ecosystem and/or watershed condition,
- Facilitating peer-to-peer (i.e., state-to-state) transfer of scientific and technical information,
- The use of biological indicators in the development and implementation (i.e., monitoring and assessment) of numeric criteria,
- The evaluation of state bioassessment programs that seek to employ biological indictors as part of nutrient or other stressor criteria, and
- Development of biological monitoring and assessment tools that may be used to detect nutrient or other stressor pollution at reach and catchment scale as well as global or regional scale stressors such as long-term alteration of hydrology, temperature and forest cover.

US EPA anticipates that the contractor shall ~~participate in and prepare for~~ provide technical support for up to two technical projects ~~consultations~~ with US EPA headquarters (HQ) biocriteria staff, US EPA regional staff, and state water quality staff. The scope, objective and schedule for each technical ~~consultations~~ project shall be defined in detail in writing with the EPA TOCOR and scientific in nature. The contractor shall maintain a written record of all ~~consultations~~ technical projects to be made available to the EPA TOCOR upon request.

SubTask 4.1: Communication/Kickoff Call

The Contractor shall contact the EPA TOCOR and schedule a kickoff project meeting with the EPA TOCOR upon notification from the EPA TOCOR of a technical consultation.

SubTask 4.2: Communication and development of a regular reporting schedule

The Contractor shall establish communication with the EPA TOCOR and develop a regular reporting schedule throughout the period of the technical consultation.

SubTask 4.3: Monthly Progress and Financial Reports

Submit and prepare monthly progress reports. The monthly progress report shall include project status, expenditures to date, unexpected problems or concerns, corrective actions, lessons learned, QA/QC activities, and next steps.

SubTask 4.4: Coordination and notification

This task requires coordination with other organizations and therefore it is particularly important that the Contractor shall notify the EPA TOCOR of issues, problems, questions, or delays as soon as they become apparent or if they are anticipated.

SubTask 4.5: Technical Project #1

The contractor shall provide technical support to gather and evaluate biological and ecological data for use in development of a BCG model for benthic invertebrate and fish assemblages in streams and wadeable rivers in the Central Great Plains. The contractor shall use existing data sets that have documented QA/QC review. Potential sources of data include: Nebraska, Kansas, Iowa and Missouri state biological monitoring datasets (publicly accessible), EPA's StreamCat data (Hill et al. 2016), Indices of Catchment and Watershed Integrity (ICI and IWI, respectively) (USEPA website, publicly accessible) and EPA NRSA data sets (USEPA website, publicly accessible). Other potential data sets may also be identified and evaluated for this purpose, including publicly accessible data sets and historical records from USGS and FWS and counties located within this region.

Specific elements of the project include:

4.5.1 Create a Database for BCG model development

4.5.1.a. Identify publicly accessible datasets from states, local governments and federal agencies for use in development of BCG models for fish and benthic invertebrate assemblages in streams and wadeable rivers in the Central Plains.

4.5.1.b. For each_fish and benthic invertebrate assemblage, evaluate availability and technical quality of datasets for use in development of the BCG models considering:

- Data quality
- Level of taxonomy
- Methods used
- Sites span range of condition from no to high level of stressors
- Coordinated monitoring of chemical and physical stressors, and,
- Availability and access to chemical and physical monitoring data

4.5.2: Facilitate BCG Development Meeting

4.5.2.a Prepare materials for introductory meeting (1/2 day) on BCG development. Materials to include powerpoint slides describing the BCG development process, milestones and role of expert panel members; and a prototype data spread sheet for an introductory site evaluation exercise.

4.5.2.b Travel to attend meeting per 4.5.2.c. The meeting is scheduled for March 3, 2002, at the USEPA regional office, Lenexa, Kansas.

4.5.2.c At the meeting present information and steps on BCG development process and respond to questions from the audience. Primary audience for presentation: state and tribal bioassessment and and criteria program scientists. The meeting will be one half day (afternoon session)on March 3, 2002.

4.5.3: Technology Transfer

4.5.3.a Prepare a short fact sheet (one to two doublesided pages) and case studies on the key lesson learned on use of historical data and peer reviewed literature in defining BCG levels 1 and 2 (pristine and near-pristine conditions) including the added value of this information in development and application of a quantitative BCG model. The lessons learned and case studies will be derived from the results of the Pacific Maritime Northwest and Coral Reef BCGs and their use of historic data and peer reviewed literature.

SubTask 4.6: Technical Project #2

The contractor shall provide technical and logistical support to the EPA TOCOR to conduct up to three webinars on advances in the science of bioassessment and biological criteria. The primary audience of these webinars are state water quality management programs – first level managers (e.g. branch and section chiefs), staff, and field crews. Topics include but are not limited to: development and application of biological condition gradients in state WQM programs – lessons learned from BCG projects to date; advances in use of diatom assemblage data to support state WQM programs; methods and indicators for assessing streams with highly variable flow.

Specific elements of the project include:

4.6.1.a. Kick off Call. The EPA TOCOR will provide webinar schedule and topics to the contractor within two weeks following TO award.

Webinar #1
4.6.2.a Prepare materials for webinar #1. Materials to include powerpoint slides and hand outs. All materials will be provided to Tetra Tech at least two days prior to the Webinar.
4.6.2.b Provide logistical support to conduct webinar. The webinar will be recorded and uploaded for public access.

4.6.2.c During the webinar, present slides and respond to questions from the audience. The contractor will also provide response to questions that may be submitted via email following the webinar. A record of all questions and answers will be created and provided to the EPA TOCOR.

Webinar #2
4.6.3.a Prepare materials for webinar #2. Materials to include powerpoint slides and hand outs. All materials will be provided to Tetra Tech at least two days prior to the Webinar.

4.6.3.b Provide logistical support to conduct webinar. The webinar will be recorded and uploaded for public access.

4.6.3.c During the webinar, present slides and respond to questions from the audience. The contractor will also provide response to questions that may be submitted via email following the webinar. A record of all questions and answers will be created and provided to the EPA TOCOR.

Webinar #3

4.6.4.a Prepare materials for webinar #3. Materials to include powerpoint slides and hand outs. All materials will be provided to Tetra Tech at least two days prior to the Webinar.

4.6.4.b Provide logistical support to conduct webinar. The webinar will be recorded and uploaded for public access.

4.6.4.c During the webinar, present slides and respond to questions from the audience. The contractor will also provide response to questions that may be submitted via email following the webinar. A record of all questions and answers will be created and provided to the EPA TOCOR.

Task 4. Deliverables

Task	SubTask	Deliverable	Due
4	4.1	Communication/Kick-off call	Within 3 days of consultations
4	4.2	Regular reporting schedule	As requested by the EPA TOCOR
4	4.3	Progress and financial reports	Monthly
4	4.4	Coordination and notifications	Immediately upon knowledge of incident
4	4.5.1.a-c.	Database and Recommendations	Two weeks after receiving final comments from the EPA TOCOR
4 4	4.5.2.a-b 4.5.3. a	Presentation on BCG development process Lessons Learned fact sheet	Two weeks after receiving final comments from the EPA TOCOR Two weeks after receiving final comments from the EPA TOCOR
4	4.6.1.a	Kickoff Call	Within two weeks of TO AWARD
4	4.6.2.a-b	Webinar #1 slides, recording, handouts, and question and answer record	Two weeks after receiving final comments from the EPA TOCOR
4	4.6.3.a-b	Webinar #2 slides, recording, handouts and question and answer record	Two weeks after receiving final comments from the EPA TOCOR
4	4.6.4.a-b	Webinar #3 slides, recording, handouts and question and answer record	Two weeks after receiving final comments from the EPA TOCOR

VIII. Acceptance Criteria:

The Contractor shall prepare high quality deliverables. Deliverables shall be edited for grammar, spelling, and logic flow. The technical information shall be reasonably complete and presented in a logical, readable manner. Figures submitted shall be of high quality, similar to those in presentations developed for national scientific meetings and should be formatted as jpeg or png files. Additional requirements specific to this TO are as follows: Electronic deliverables must be in an original file format that can be supported by EPA after the end of the Period of Performance of the TO. The standard office software at EPA is MS Office. Text deliverables shall be provided in Microsoft Word 2010 or compatible format.

Appendix A. Tetra Tech SOP for Statistical Analyses

SOP Statistical Analyses
Revision No. 0
Date: 03-09-17
Page 1 of 7

Standard Operating Procedure TT-FFX-SOP-O-002

Statistical Analyses

Prepared by:	Name Jon Harcum, Ph.D.	Title Environmental Engineer
	Signature Jon Harcum	Date
Approved by:	Name John Hochheimer, Ph.D.	Title Technical Monitor
	Signature	Date 3/9/17
Approved by:	Name Susan Lanberg	Title QA Officer
	Signature	Date

Scope and Applicability: The Tetra Tech Project Manager, Statistical Analyst, QA Officer, and QC Officer should refer to this procedure to ensure that the quality assurance/quality control (QA/QC) requirements set by our clients are met. Statistical analysis of data covers a wide range of calculations and graphical visualization techniques. Relevant QA/QC practices for statistical analyses include ensuring that the analyses are correct, reproducible, and transparent. To ensure that we meet the QA/QC requirements set by our clients, statistical calculations must undergo QC reviews and those reviews must be documented in the project files. The Tetra Tech Project Manager and QA Officer will communicate to the Statistical Analyst whether specific documentation of QC reviews is required for a particular task.

The appropriate level of statistical analysis and corresponding level of QC review will vary with project goals, available data, resources, and the decisions to be made. At the beginning of a particular project, the Statistical Analyst will provide recommendations to the Tetra Tech Project Manager regarding statistical methods to be used for analyzing the data. At this time, the Statistical Analyst and Project Manager should discuss the approximate level of effort needed for the various analyses and corresponding level of QC review required. Follow-up discussions should be held throughout the duration of the project, as needed, to clarify the analyses to be performed, level of QC review needed, and level-of-effort required.

- It should be noted that analyses that are expected to be used to inform future, more detailed analyses can be performed with a cursory-level QC review so long as work products are identified as such in their transmittal to the client and in progress reports.
- Analyses that directly inform decisions/actions (e.g., remediation, compliance decisions, regulatory action, source control, capital investment) require a higher, standard-level QC review.

This document describes the following topics as related to ensuring the quality of Tetra Tech's statistical analyses: method selection, best practices, and QC.

Responsibility and Personnel Qualifications: The Tetra Tech Project Manager supervises the overall project and is responsible for coordinating project assignments; establishing priorities and schedules; ensuring completion of high-quality projects within established budgets and schedules; providing guidance, technical advice, and evaluating the performance of those assigned to the project; implementing corrective actions; preparing or overseeing preparation and review of project deliverables; and providing support to the client in interacting with the project team, technical reviewers, and others to ensure that technical quality requirements are met in accordance with the client's objectives. The Statistical Analyst is responsible for performing the statistical calculations and analyses and the QC Officer is responsible for checking those activities. A QC Officer is a technical staff member who is familiar with the project tasks but does not participate in the task or subtask that he or she checks. The QA Officer with assistance from the assigned QC Officer, will monitor QC activities to determine conformance with project QA/QC requirements. The Tetra Tech Project Manager and QA Officer will communicate to the Statistical Analyst whether specific documentation of QC reviews is required for a particular task.

Procedures

1. Method Selection: Based on the characteristics of available data and the project's needs, the Tetra Tech Project Manager, in consultation with the client and the Statistical Analyst, will determine whether common exploratory summary statistics and/or standard graphical presentations will be needed for a particular project, or whether more advanced predictive procedures (e.g., applying a range of hypothesis tests, applying multivariate tools, developing empirical models) will be required. Some examples of various procedures are listed below.
    - Common summary statistics include counts of observations and distribution characteristics (e.g., mean, standard deviation, coefficient of variation, variance, median, percentiles).
    - Standard graphical presentations (e.g., distribution plots, scatter plots, boxplots, time series).
    - Parametric and non-parametric hypothesis tests (e.g., t-test, analysis of variance, Kruskall-Wallis).

- Multivariate tools (e.g., principal components analysis, clustering analysis, canonical correspondence analysis, discriminant analysis, non-metric mulitdimensional scaling).
- Models (e.g., linear and non-linear regression, general additive models, general linear models, Bayesian hierarchical models).

When deciding which statistical procedure to apply to any data set, it is essential to consider the characteristics of the data, which will help determine the appropriate statistical analysis. Some common characteristics of data include one or more of the following:

- Presence of outliers, extreme low or high values that occur infrequently, but usually somewhere in the data set (outliers on the high side are common) resulting in skewed distributions.
- Variance heterogeneity.
- Non-normal distribution.
- Small sample size.
- Censored data – concentration data reported above or below one or multiple detection limits or reporting values.
- A lower bound of zero (e.g., no negative concentrations are possible).
- Missing values.
- Irregular sampling.
- Strong seasonal patterns.
- Autocorrelation – consecutive observations strongly correlated with each other.
- Dependence on other uncontrolled or unmeasured variables – values strongly co-vary with such variables as streamflow, precipitation, or sediment grain size.
- Measurement uncertainty.

Common Tools/Software: There are a wide variety of computer tools/software available to support statistical analyses including spreadsheets (e.g., Excel), databases (e.g., Access, SQL), commercial statistical packages (e.g., SAS, Minitab, Systat), customized software (software created by a state/federal agency or a third party vendor designed for a particular analysis, e.g., ProUCL, EPIWEB), and programming code (e.g., FORTRAN, C++, Python, R). Hand calculations can also be used.

The functionality of these tools overlaps, yet different numerical results are sometimes computed when using different tools. For example, a key part in estimating percentiles is to assign ranks to the observed data. Some spreadsheet software programs assign the minimum rank to tied values rather than assigning a rank that is equal to the median of the ranks if the observations had not been tied. Other commercial software may include multiple formulas for computing percentiles, which the user can select. The outcome is that different percentiles might be computed among different software packages. Similarly, different analysts can compute different numerical results when applying similar steps, but simply in a different order (e.g., the logarithm of the average is not equal to the average of the logarithms). It is important that the original analyst and person performing QC checks be aware of these potential differences and their impact on the analyses and independent checking of results. *Overall Justification and Documentation of Methods Used*: Common summary statistics and standard graphical presentations that follow normal practices for the type of data being evaluated require little or no justification for their usage. Method selection for hypothesis testing, multivariate procedures, model development, or more advanced procedures should be made by an experienced analyst with justification included in the corresponding report. Citing similar analyses available from applicable guidance/methods documents or peer-reviewed literature is sufficient. Methods selected from the Internet, gray literature, software literature, or presentations require additional narrative to document why a particular method is, or might be expected to be, appropriate.

2. Best Practices: This section provides a list of best practices that can be implemented to reduce errors in statistical analyses and improve the overall work product. It is the responsibility of the Tetra Tech Project Manager and delegated Statistical Analyst to identify which practices are appropriate for a particular task.

   - *Overall*:
     - Maintain original copies of source data, related metadata, and the 'ready-to-analyze' data sets. See the Secondary Data Management SOP for more information on data organization and management. Use a naming convention for files that is understandable to you and others, and is designed in way that helps ensure that version control is maintained throughout the project (e.g., use of dates, version numbers, draft, final).
     - Develop a written technical description of the analysis. This description can be written before beginning analyses and/or developed as a living document throughout the course of the project.
     - Identify analysis milestones where data should be exported/saved to improve transparency and reproducibility, as well as for QC analyses and record keeping.
     - Perform statistical analyses in a similar fashion throughout the project. Document deviations in the technical description of the analyses.
     - Document the name, version, and, where applicable, the source code of the software used to perform analyses. This is applicable for commercial and open source software.
     - Give titles to objects in the spreadsheet, database, or software that lend an understanding to the purpose of the object. For example, a database query entitled 'selectData_v02' might be a useful object title for the second version of a query that selects data from a primary source table.

- *Hand Calculations*:
    - Hand calculations should be legible and document their purpose.
    - Scan hand calculations so they can be maintained as electronic documents with other documentation.
- *Spreadsheets*:
    - Include a documentation tab that includes information about the spreadsheet as a whole and a description of the other tabs.
    - Organize tabs from left to right in the same order as the analysis steps.
    - Organize calculations within a tab from left to right and/or top to bottom.
    - Make judicious use of named cells and relative/absolute cell addresses to allow maximum use of ‘fill-down’ and ‘fill-right’ options.
    - Limit cell and font styles for highlighting information that could be derived from examining the data. For example, it is an acceptable practice to set a cell color to “yellow” to help visualize all p-values less than 0.05. It is not a typically accepted practice to highlight statistically significant regression slopes but not show/include the actual p-values.
- *Commercial Statistical Packages*:
    - Document the name and versions of the software used.
    - Document the steps and settings used to implement calculations that are menu/interactively implemented.
    - Develop macros to implement repeated tasks.
- *Customized Software*:
    - Document the name and versions of the software used.
    - Document the steps and settings used to implement calculations that are menu/interactively implemented. (Note that it is a common practice for software packages to be developed by a third party on behalf of a state or federal agency to perform a very specific set of analyses that are not directly available in commercial software. While these software packages may be well tested for the primary work flow, they may not be as well tested or error proof, if used in a non-conventional manner. Therefore it important that the analyst have an understanding of the basic work flow of the software package and document its usage.)
- *Programming Code (e.g., FORTRAN, C++, Python, R)*
    - Maintain all source code, and if applicable compiled code, used to perform all analyses for documentation and future use. This allows for transparency and repeatability of the analysis.
    - Where practicable, repeat the analyses with a separate tool to verify the results or code and/or independently unit test the source code.

Pertinent QA and QC Procedures

1. The appropriate level of QC will vary with project goals, available data, resources, technical approach, and the decisions to be made. The principal QC questions include the following:

    - Was an appropriate method chosen and applied?
    - Were the statistics computed and graphics created correctly?
    - Were the statistics and graphics representative of the data?
    - Were method assumptions met?
    - Were the results presented correctly?

2. Selection of a particular method depends on the data and the analysis objectives. Calculating summary statistics and developing basic graphics can normally be performed by any basic environmental consultant/staff member. Exceptions might include calculations with censored data or other non-standard data. Advanced statistical calculations and related output (tabular, graphic, etc.), including, but not limited to, hypothesis testing, multivariate tools, empirical models, and statistical simulations will generally benefit from oversight by an experienced analyst. However, it should be noted that multiple methods might be applicable for a given project and set of data (see Overall Justification and Documentation of Methods Used section above).

3. As described in the introductory section of this document, analyses that are expected to be used to inform future, more detailed analyses can be performed with a cursory-level QC review so long as work products are identified as such in their transmittal to the client and in progress reports. While a cursory-level QC review could include some independent checking of calculations, a cursory-level review may also be limited to reviewing selected sections of a technical report that focus on the data summary, technical approach, and results sections.

4. For statistical calculations performed using analysis software for which the results will be used to directly inform decisions/actions (e.g., remediation, compliance decisions, regulatory action, source control, capital investment), calculations will be independently checked using a standard-level review. As used here, independent calculations can refer to a different analyst performing the same analysis, or they may refer to the same analyst performing the same analysis using a different software tool. Some projects might require complete independent checking of all calculations. This requirement, or even standard-level QC, could cause a significant resource burden in projects that involve multiple iterations and modifications. Thus, the Statistical Analysts should confer with the Project Manager to confirm the best timing for QC checks to best use the available budget.

5. With today's computer technologies, it is more appropriate in some instances to perform targeted checking rather than rely on a fixed "10 percent of all calculations" rule when performing independent calculations. A standard-level review consists of up to 10 percent independent recalculations of computations and graphs, but no less than two examples of each computed statistic and two examples of each graphic type. More calculations (up to 10 percent) should be reviewed if data sets or points are processed individually while fewer

checks (no less than two examples of each computed statistic and two examples of each graphic type) are appropriate for automated to semi-automated procedures. Selection of which statistics and graphs to check should include targeting unique and unusual record types that might stress the calculation and graphing process. All identified calculation errors will be corrected and the Tetra Tech QC Officer will perform a follow-up review of the corrected components to ensure that the errors have been corrected. Where changes are made to previously checked analyses or changes are made to address the results of QC checks, it is normally expected that only the changed/corrected components of the analysis and the dependent, follow-on components would be subject to checking/re-checking. For example, if a change or correction is made to an analysis (e.g., substituting a maximum likelihood technique for a least squares estimation method) then it would not be normally expected to
re-check data transformation steps the led to creating the 'ready-to-analyze' data set. In cases where codes are developed to perform statistical calculations, codes and changes to codes should be checked and tested for reproducibility by a qualified QC Officer, and if possible, run on independent software.

6. In the majority of instances, statistical calculations will be performed using analysis software. In (relatively uncommon) circumstances where statistical calculations are primarily performed by-hand, a Tetra Tech QC Officer will independently recalculate 10 percent of these calculations to ensure they were performed correctly. If more than 1 percent of the data calculations are incorrect, the Tetra Tech QC Officer will independently check the remaining calculations to ensure they are correct. All identified errors will be corrected.

Appendix B. Tetra Tech SOP for Secondary Data

Standard Operating Procedure	TT-FFX-SOP-O-001

Secondary Data Management

Prepared by:	Name Alex DeWire	Title Environmental Scientist
	Signature	Date 3/9/17
Approved by:	Name John Hochheimer, Ph.D.	Title Technical Monitor
	Signature	Date 3/9/17
Approved by:	Name Susan Lanberg	Title QA Officer
	Signature	Date

Scope and Applicability: This procedure provides an overview of secondary data processing and management techniques. Secondary data are data that were collected under a separate effort for some other purpose, whereas primary data are original data collected for a specific project. Secondary data analyses are becoming increasingly common because technological advances have made it possible to store and remotely access large amounts of data. Secondary data processing can be used to further refine and process data compiled from existing data sources. Information on evaluating secondary data sources for quality is provided in the quality assurance project plan **(QAPP)** or equivalent documentation prepared for a particular project.

This procedure acknowledges that standard practices and protocols vary temporally and differ among various monitoring groups, states, and agencies. Secondary data processing techniques aim to detect and account for inconsistency in a data set compiled from multiple sources. The goal is to improve the comparability and consistency of secondary environmental monitoring data used for a particular project.

This document describes the following topics as related to ensuring the quality of Tetra Tech's secondary data management: data acquisition and documentation, data quality considerations, data organization, and data transformation. A quick reference list of common steps used for data management and processing developed specifically for water quality data, is also included as Attachment 1.

Responsibility and Personnel Qualifications: The Tetra Tech Project Manager, Data Manager, Quality Assurance (QA) Officer, and Quality Control (QC) Officer should refer to this procedure to ensure that the QA/QC requirements set by the client are met. The Tetra Tech Project Manager supervises the overall project and is responsible for coordinating project assignments; establishing priorities and schedules; ensuring completion of high-quality projects within established budgets and schedules; providing guidance, technical advice, and evaluating the performance of those assigned to the project; implementing corrective actions; preparing or overseeing preparation and review of project deliverables; and providing support to the client in interacting with the project team, technical reviewers, and others to ensure that technical quality requirements are met in accordance with the client's objectives. The Tetra Tech Data Manager is responsible for performing the data processing and management activities and the Tetra Tech QC Officer is responsible for checking those activities. A QC Officer is a technical staff member who is familiar with the project tasks but does not participate in the task or subtask that he or she checks. The Tetra Tech QA Officer, with the assistance of the assigned QC Officer, will monitor QC activities to determine conformance with project QA/QC requirements. The Tetra Tech Project Manager and QA Officer will communicate to the Tetra Tech Data Manager whether specific documentation of QC reviews is required for a particular task.

References:

Boslaugh, S. 2007. *Secondary Data Sources for Public Health: A Practical Guide*. Cambridge University Press.

Chapman, A.D. 2005. *Principles of Data Quality*, Version 1.0. Report for the Global Biodiversity Information Facility, Copenhagen. http://niobioinformatics.in/pdf/workshop/Data%20Quality.pdf.

Edwards, P.J. 1986. *Conversion Factors and Constants Used in Forestry, with Emphasis on Water and Soil Resources*. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. NE-GTR-113. November 1986. 12 p. http://www.treesearch.fs.fed.us/pubs/4159.

U.S. EPA (U.S. Environmental Protection Agency). 2009. *EPA New England Quality Assurance Project Plan Guidance for Environmental Projects Using Only Existing (Secondary) Data.* EPA-820-S-10-001. U.S. Environmental Protection Agency New England, Quality Assurance Unit, Office of Environmental Measurement and Evaluation. http://www.epa.gov/region1/lab/qa/pdfs/EPANESecondaryDataGuidance.pdf.

U.S. EPA (U.S. Environmental Protection Agency). 2012. *Guidance for Evaluating and Documenting the Quality of Existing Scientific and Technical Information Addendum to: A Summary of General Assessment Factors for Evaluating the Quality of Scientific and Technical Information*. Prepared for the U.S. Environmental Protection Agency, Science and Technology Policy Council, Washington, DC. http://www2.epa.gov/sites/production/files/2015-05/documents/assess3.pdf.

U.S. EPA (U.S. Environmental Protection Agency). 2014. *Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams*. EPA/600/R-13/170F. Global Change Research Program, National Center for Environmental Assessment, Washington, DC. Available from the National Technical Information Service, Springfield, VA, and online at https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=280013&CFID=87634392&CFTOKEN=78487573.

Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A. 2006. *Guidelines and Standard Procedures for Continuous Water-Quality Monitors—Station Operation, Record Computation, and Data Reporting.* U.S. Geological Survey Techniques and Methods 1–D3, 51 p. + 8 attachments. http://pubs.water.usgs.gov/tm1d3.

Procedures

1. Data Acquisition and Documentation: Data acquisition involves the process of obtaining and documenting data of various types (e.g., water quality sampling data, spatial data, remote sensing imagery, survey results, 303(d) impairment or 305(b) assessment data, TMDLs, discharger data) using search criteria for the project determined in consultation with the client. Data acquisition must be a repeatable and transparent process. At the beginning of a project, the Tetra Tech Project Manager will consult with the Tetra Tech QA Officer to determine applicable documentation requirements. Data Managers must automate and document each aspect of data acquisition. Data Managers should avoid manual transcription (non-automated data processing) because of the potential to introduce error into the data set. However, automated processes must be properly checked and verified to ensure error-free results.

   The important aspects of data documentation include keeping records of the data source (e.g., URL, agency providing the data, version), the access date, and the access procedure. At the beginning of the project, the Tetra Tech Project Manager will consult with the Tetra Tech QA Officer to determine applicable documentation requirements. Screen captures of search results (refer to Figure 1) can be a quick and effective way to document aspects of the download procedure. Figure 1 is an example of a screen capture of selection criteria entered in the Water Quality Portal: State = "Kentucky"; Site Type = "Stream" and "Lake, Reservoir, Impoundment"; Sample Media = "Water"; Characteristic Group = "Biological" and "Nutrient"; Date Range = "01-01-2003" to "12-31-2013"; and Database = "STORET" and "NWIS". Alternatively a README text file or word document can be saved with the original data to document this information. If data are acquired via e-mail or file transfer protocol (FTP), save a copy of the original e-mail or FTP access instructions.

2. Data Quality Considerations: At the beginning of a project, the Tetra Tech Data Manager will consult with the Tetra Tech Project Manager and QA Officer for applicable data quality considerations. The advantages of using secondary data include cost and time savings, more extensive data availability, and the potential for analysis by experts not available at smaller scales. However, secondary data have inherent disadvantages because the data were not

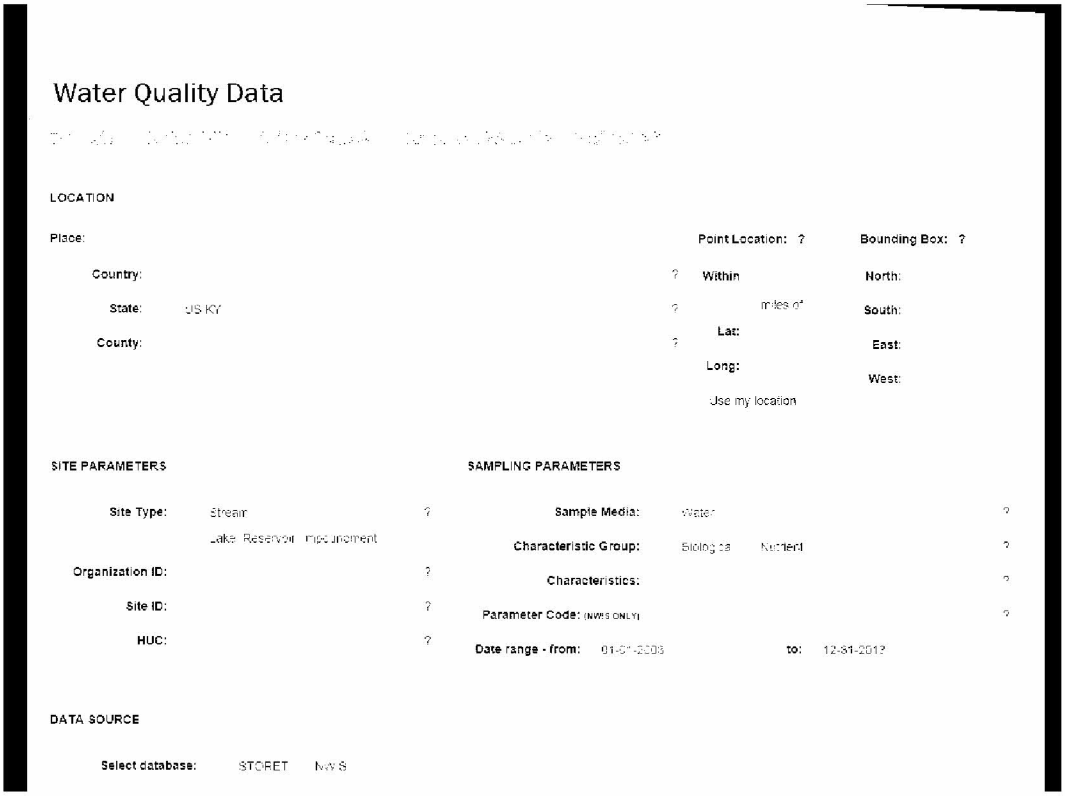

Figure 1. Example screen capture of search criteria selections in the Water Quality Portal[1]

collected by those conducting the analysis and were often not collected to answer the specific question(s) of the current analysis.

For example, data might have been collected for different variables, geographic regions, or sampling frequencies. In addition, because the analyst did not participate in the sampling design or sampling process, the methods and quality of analysis might be unknown. Data might have been collected using different sampling techniques (grab sampling versus composite sampling or random sampling versus targeted sampling). The laboratory or sampling processing methods might also have differed. Differences in technique or documentation can contribute to variability in the data set when multiple secondary data sources are combined for an analysis. Errors in spatial position and taxonomic identification are particularly common in environmental data (Chapman 2005).

The amount of documentation associated with a particular source often varies widely. Documentation of the source, including metadata documented in project reports, validation reports, and any database information, should be maintained along with the data. Research into the origin and documentation of a data source might be necessary to properly evaluate the data source. Potential sources for this documentation might include the website for the agency or group that collected the data, published reports, research articles, and personal communication with the original researcher or monitoring group staff.

---

[1] http://www.waterqualitydata.us/portal.jsp

Consider this series of general questions when evaluating the quality of any secondary data source and the applicability of the data to the current project (Boslaugh 2007):

- What was the original purpose for which the data were collected?
- What kind of data are they, and when and how were the data collected?
- What data processing and/or recording procedures have been applied to the data?

Also consider the following questions, which are more specific to water quality data, when evaluating a water quality data source (USEPA 2009):

- Were the data generated under an approved QAPP or other documented sampling procedure?
- If multiple data sets are being combined, were the data sets generated using comparable sampling and analytical methods?
- Were the analytical methods sensitive enough (detection limits) to meet project needs?
- Is the sampling method indicated (e.g., grab, composite, calculated)?
- Was the sampling effort representative of the waterbodies of interest in a random way, or could bias have been introduced by targeted sampling?
- Are the data qualified? Are sampling and laboratory qualification codes or comments included? Are the qualification codes defined?
- Is sufficient metadata available about variables like sampling station location, date, time, depth, rainfall, or other confounding variables?

Specific evaluation criteria for each parameter being considered should also be applied across all sources. Although many water quality data sets include QC samples labeled as duplicate, split, spiked, blank, and so forth; re-checking QC samples is beyond normal practices for secondary data analyses. Rather, it is expected that project-specific QAPPs or similar documentation describing the performance criteria evaluated and met are available for data obtained from peer reviewed sources or from federal, state, or local government reports or data compilations. If this documentation is not readily available, Tetra Tech will consult with the client to determine how much effort should be expended to find reports or metadata that might contain that information. Nevertheless, establishing minimum data requirements for secondary data analyses is often valuable. For example, water chemistry data might require locational information, date, time (optional), depth (optional), chemical name, units, numerical result, and data qualifiers. Specific requirements would depend on project specific needs. For example, it might be necessary to identify outliers or changes in analytical methods. In those cases where requested by the client, QC samples can be used to double- check sample accuracy (e.g., whether duplicate samples are within 15 percent of the corresponding sample).

The National Environmental Methods Index (NEMI)[2] provides a searchable compendium of environmental methods. Different scientific methods can be compared using the method summaries, which also include literature citations. Generally, parameters monitored using different methods should not be combined unless the techniques are documented to be scientifically comparable. EPA also has compiled training materials to detect improper laboratory practices when working with monitoring data.[3]

3. Data Organization: After acquisition, data should be organized and stored. The original unaltered data and "as analyzed" data files should be archived to ensure replicability of the work. Data sets are constantly being updated, so without the original data, replicating an analysis is often impossible. If you are combining data from multiple sources, include information documenting the source of the data in spreadsheets or databases. For water quality data, generally seek to organize data into one of the following hierarchical structures: (1) *source → station → sample* or (2) *source → station → sample → result* so the data are ready for a variety of analyses.

   A relational database, such as Microsoft Access or an Oracle-based system, is an efficient method used to organize multiple related tables. For water quality data, these tables can include station-level tables, sample-level tables, and lookup tables. A primary key or unique identifier, such as a numerical field or a composite primary key made up of multiple fields (e.g., station-sample-date-time-depth), should be assigned to each record. Each table should have a primary key. Foreign keys are fields in one table that uniquely identify a row in another table, often called a lookup table. Figure 2 provides an example of sample-level and lookup relational tables with the primary keys and foreign keys identified. Referential integrity should be maintained such that each foreign key corresponds to the value of a primary key or a null value in a lookup table.

Sample ID	Parameter	Result	Remark
1	Total Nitrogen	1.4	DQ
2	Total Nitrogen	1.4	
3	Nitrate	0.5	
4	Total Nitrogen	2.4	DQ
5	Total Nitrogen	2.4	
6	Total Phosphorus	0.08	T

Remark	Description	Action
W	cloudy	NA
DQ	Duplicate Quality Assurance Sample	REMOVE
T	Sample exceeding holding time	REMOVE
?	Data should be rejected	REMOVE
*	Exceeded MDL	Flag

Figure 2. Example of relational tables with primary and foreign keys

A disciplined file structure and file naming convention can improve version control management. Label files with unique identifiers such as dates or other indicators of version control. Include a documentation table that identifies the database objects (tables, queries,

[2] www.nemi.gov
[3] http://www.epa.gov/quality/trcourse.html#monitoring

reports, etc.). Maintain the original data in a read-only database and ‘link in’ to the analysis database to prevent accidental changes to original data.

Large (e.g., multiple-gigabyte) files sizes are increasingly common, especially with remote sensing imagery, spatial data, or large databases. Consider the storage and backup requirements of these large files. For example, you might need a separate server to accommodate the data needs for a project. If you are working with multiple people, consider the implications of file storage choices for file transfer. Spatial data management has some unique considerations discussed in a separate Geospatial and Data Management QA/QC Procedures document.

Sample-level water quality data are often stored in a vertical format with a column for parameter or characteristic name and a column for result values, as shown in Figure 3. After data transformations, but before statistical analyses, it is often more convenient and space- efficient to convert the data to a horizontal format, in which each parameter of interest has its own column and results for that parameter are reported in the parameter column. This approach allows for simpler identification of paired sampling data (samples taken from the same station-date-time) for multiple parameters, which in turn makes identifying relationships among parameters possible.

Vertical Format

Date/Time	Characteristic	Result
1/1/2000 15:00	Nitrogen, Total	1.5
1/1/2000 15:00	Nitrate	0.8
1/1/2000 15:00	Phosphorus, Total	0.5
1/1/2000 15:00	SRP	0.1
1/1/2000 15:00	Orthophosphate	0.2
6/1/2000 9:00	Nitrogen, Total	2.2
6/1/2000 9:00	Nitrate	1.3
6/1/2000 9:00	Phosphorus, Total	0.2
6/1/2000 9:00	SRP	0.1
6/1/2000 9:00	Orthophosphate	0.1

Horizontal Format

Date/Time	Nitrogen, Total	Nitrate	Phosphorus, Total	SRP	Ortho-phosphate
1/1/2000 15:00	1.5	0.8	0.5	0.1	0.2
6/1/2000 9:00	2.2	1.3	0.2	0.1	0.1

Figure 3. Example of water quality data in vertical (left) and horizontal (right) format

Effective data organization can improve the efficiency with which data can be checked for errors, processed, transformed, and documented. Sorting by location, source, parameter, or other column allows error-checking and transformation to be automated, which improves not only efficiency but also QA.

Aligning matching records can be arduous if not already performed. For example, StationID might differ among sampling visits and would need to be checked using latitude/longitude information (which should be associated with each station). When combining data sets, checks of additional records for near-concurrently collected samples should be performed. These additional records could include chemical species, taxonomic names, and dates. For example, if habitat data were collected on one day and fish were collected 2 days later, there should be an indicator that those data are (or are not) comparable for analysis.

4. <u>Data Transformation</u>: After acquiring the data, archiving the original unaltered data, performing QC checks, and organizing the data, the data often need to be transformed or processed to put them in a comparable format. Data transformation should be organized, systematic, repeatable, and automated as much as possible to reduce the chance of error and minimize the level of effort common to manual transformation.

   This task often involves manipulating the data from the original data source to a 'ready-to- analyze' data set. The original data source can be one to multiple files with the same or different data structure.

Pertinent QA and QC Procedures

1. Relevant QA/QC practices for secondary data management include ensuring that the data processing steps are correct, documented, well organized, reproducible, and transparent. To ensure that we meet the QA/QC requirements set by our clients, data processing steps must undergo QC reviews and those reviews must be documented in the project files. The Tetra Tech Project Manager and QA Officer will communicate to the Data Manager whether specific documentation of QC reviews is required for a particular task.

2. The appropriate level of secondary data management and corresponding level of QC review will vary with project goals, available data, resources, and the decisions to be made. At the beginning of a particular project, the Data Manager will provide recommendations to the Tetra Tech Project Manager regarding methods to be used for processing and managing the data. At this time, the Data Manager and Project Manager should discuss the approximate level of effort needed for the various processing steps and corresponding level of QC review required. Follow-up discussions should be held throughout the duration of the project, as needed, to clarify the analyses to be performed, level of QC review needed, and level-of-effort required.

   - It should be noted that cursory level compilations of data that are used to inform whether more robust data compilations can be prepared can be developed with minimum QC review so long as intermediate work products are identified as such in their transmittal to the client and in progress reports.
   - Data compilations that directly inform decisions/actions (e.g., remediation, compliance decisions, regulatory action, source control, capital investment) require a higher level of QC review.

3. For replicability and QA, maintain a copy of the raw, unaltered downloaded data and related metadata, including variable names/definitions. These raw data can also be important in troubleshooting processing errors introduced during the analysis and in maintaining version control. Data are increasingly dynamic with real-time data uploads and can be updated by data owners at any time. Also, maintain the 'ready-to-analyze' data sets. A 'ready-to-analyze' data set refers to the data set after all processing and transformations have been completed, prior to analysis. At a minimum, the original data, the 'ready-to-analyze' data, and all project deliverables should be electronically stored where automated backups are made on at least a daily basis for the purposes of catastrophic recovery. This can include

office servers or cloud-based solutions. Test analyses and temporary files do not require this type of storage or backup.

4. Other QC checks could leverage the spatial aspect of the data. Stations should be mapped to verify that the data fall in the correct political boundary, ecoregion, waterbody type, or other descriptive spatial factor. Data that reportedly reflect sampling of a lake in Kansas but have coordinates in the Pacific Ocean should call the accuracy of the data and/or the coordinates into question, as should the occurrence of a fish species in a lake in Kansas, not found in inland lakes. Continuous data have a different set of quality concerns such as time stamps, drift in measurements over time, and trimming of the period of record to eliminate records that are out of water, choked in sediment, or exhibiting drift. These concerns are not addressed in this Tetra Tech QA/QC document. For further information on continuous data quality concerns, refer to draft guidance from USEPA and USGS on this topic (USEPA 2014; Wagner et al. 2006).

5. Different data sets can have different naming conventions, units, etc., that need to be unified. The principal QC questions include the following:
   - Was the process documented?
   - Were all data files processed?
   - Were all data records processed (e.g., no dropped records)? If not, were excluded data justified?
   - Were transformation and reshaping steps implemented correctly?

6. As described earlier in this document, cursory level compilations of data that are used to inform whether more robust data compilations can be prepared can be developed with a cursory-level QC review so long as work products are identified as such in their transmittal to the client and in progress reports. With the exception of these cursory-level data compilations, independent checks of data compilations should be performed to ensure we meet the client's QA requirements. Applicable QC checks for data reshaping and transformations tasks are summarized in Table 1.

Table 1. Applicable QC checks for data reshaping and transformations

QC #	Description	Cursory Level Review	Standard Level Review
1.1	Confirm that the reshaping and transformation steps are documented with the data.	X	X
1.2	Confirm that the files processed and record counts of the end product meet expectations.	X	X
1.3	Review meta information prepared by the original analyst that documents transformations and reshaping.	X	X
1.4	For each different file type (i.e., a file with different structure or legacy), confirm the first, last, and a selected middle portion of the data were transformed and reshaped correctly.*		Up to 10% of processed data files, but no less than two data files of each type**

QC #	Description	Cursory Level Review	Standard Level Review
***Evaluating the first and last portions of data helps confirm that no records were accidentally dropped during processing. Selection of the middle portion of the data to check should be done by targeting unique and unusual record types that might stress the transformation and reshaping processing. ** More files should be reviewed (up to 10%) if files are processed individually while fewer files are appropriate for automated to semi-automated procedures.**			

This section describes cursory- and standard-level QC checks that should be performed. Some projects might specify complete independent checking of an entire data compilation. This specification or even standard-level QC could cause a significant and, perhaps unnecessary, resource burden in projects that involve multiple iterations and modifications; thus the Data Manager should confer with the Project Manager to confirm the most cost-effective and efficient process for QC checks.

For data compilations that will be used to directly inform decisions/actions (e.g., remediation, compliance decisions, regulatory action, source control, capital investment), processed data will be independently checked using a standard level review. This standard review consists of independently checking each different file type (i.e., a file with different structure or legacy) and confirming the first, last, and a selected middle portion of the data were transformed and reshaped correctly. Evaluating the first and last portions of data helps confirm that no records were accidentally dropped during processing. Selection of the middle portion of the data to check should be done by targeting unique and unusual record types that might stress the transformation and reshaping processing. More files (up to 10 percent) should be reviewed if files are processed individually while fewer checks (no less than two data files of each type) are appropriate for automated to semi-automated procedures.

All identified data processing errors will be corrected and the Tetra Tech QC Officer will perform a follow-up review of the corrected components to ensure that the errors have been corrected. Where changes are made to previously checked compilation or changes are made to address the results of QC checks, it is normally expected that only the changed/corrected components of the compilation and the dependent, follow-on components would be subject to checking/re-checking. For example, if a change or correction is made to an analysis (e.g., substituting a maximum likelihood technique for a least squares estimation method) then it would not be normally expected that data transformation steps that led to creating the 'ready-to- analyze' data set would need to be re-checked.

Frequently, data column names as well as values (e.g., parameter names, comment fields, and result values) are not consistent between different data sources or even within a single source. A more detailed description of data source fields common to water quality data is provided in Attachment 2. To combine data while maintaining the original data, it is good practice to create additional user-specified fields to represent common parameters, standardized comments, and comparable values. Creating user-specified fields allows for correcting errors and performing transformation while retaining the original data in separate fields. Thus, the opportunity to go back to the original data is maintained. Maintaining documentation of data transformation and error correction is especially important when the processes are being performed by people other than the primary data collector.

Creating user-specified fields provides an opportunity to convert units to like units, standardize parameter names, interpret comment fields, convert non-detect values, or institute other data transformations. For instance, a user-specified data qualifier field might be used to flag or exclude blank samples or samples with non-numeric characters in the value field. Figure 4 provides an example of how user-specified fields might be used to convert field names and units and interpret comment fields. Another important use for user-specified fields is creating a column that documents the original source and the row ID of the original source when merging data, so that if systemic issues are found in a source, they can be resolved and processed more effectively. A quick reference guide of procedures to process water quality data is provided in Attachment 1.

Sample ID	Parameter	Result	Units	Comment	PARM	RESULTVALUE (mg/L)	REMARK
1	Total Nitrogen	1.4	mg/L		TN	1.4	KEEP
2	Nitrogen	19000	µg/L	Sampler Error	TN	19	REMOVE
3	Nitrate	0.8	mg/L	Estimated	NO3	0.8	REMOVE
4	Nitrogen as N	2.4	mg/L		TN	2.4	KEEP
5	Total Nitrogen	2400	µg/L		TN	2.4	KEEP
6	Nitrate as N	500	µg/L		NO3	0.5	KEEP

Figure 4. Example user-specified fields

Unintended data duplication is frequently present in water quality data sets. It might be the result of obtaining the same data from different sources, or simply data entry error. This phenomena, should not be confused with field or laboratory duplicate samples which are commonly performed for QA/QC purposes, including evaluating data precision. Unintended duplication can be present within a single data source or among different data sources. Merging two data sets sometimes creates new inconsistencies and duplication. Unintended duplication can skew and bias data. Duplicate values should be flagged and screened from the analysis as much as possible.

Some samples might resemble duplicate entries but actually have different depths, times, or other distinguishing features. If the only fields that are different are descriptive fields, such as comment fields, that might be an indicator of duplication. The organization ID and sampling name can be good indicators that duplication is present, but also look for duplicate values in the data over the same time frame. For example, several identical numerical values on the same day might indicate duplicate data. Sorting the data chronologically and looking for duplicate sample results is one way to begin to identify duplication. Excel has features to identify and highlight duplicate values in a field; when the data are sorted chronologically, Excel can identify potential duplicates. Duplicate records should be flagged using a user-specified field but generally not deleted. Simply deleting unintended duplicate data (i.e., not field or laboratory duplicate samples), rather than flagging and excluding the data, creates a potential for error and data loss that is difficult to identify.

Attachment 1. Quick Reference Guide of Procedures to Process Water Quality Data

These procedures include examples of the types of checks that are performed—not every check to possibly perform. Site-specific steps will apply to many data sets. These steps do not necessarily need to be performed in sequential order and may be iterative.

✓ **Data Acquisition/Organization**

Acquire data and companion metadata. Maintain a copy of all original files. Document the data source, access date, and the download procedure.

Start a recording sheet to record decisions and selections to review for quality control and data archive. Organize data in a spreadsheet or relational database. Organize data using a hierarchical structure (e.g., source→station→sample or source→station→sample→result).

Data formatting

- Convert "as text" values to numbers. Check for non-numeric characters in numeric fields.
- Label all blank cells as blanks to avoid conversion to zero, remove all inappropriate zeros (e.g., chemistry methods rarely measure a true 0, if they have an MDL).

Review data dictionaries and field names before combining data from multiple sources into a spreadsheet or database format—do not assume that field names are equivalent.

Utilize exploratory data analysis techniques such as summary statistics or graphical techniques.

Data Processing

Generally – do not delete data. Add a screening column to track decision-making and remove records. Maintain removed records in separate file with justification.

Compare the geographic/temporal scope of the data to the project objectives—it might not be necessary to process all data from a given data set. Map stations in GIS to further refine and select data based on analysis selection criteria. Conduct quality assurance checks based on spatial location.

Check for unintended duplicate entries (i.e., not field or laboratory duplicate samples). Identify and screen those samples that are duplicates. Check for samples or results that do not have stations.

Interpret data qualifiers and comments (e.g., spikes, blanks, duplicates, holding time, errors). Screen samples based on an interpretation of the data qualifier remark codes.

Check each field for inconsistencies. Screen undesired components. Examples include:

- Coordinates – Are lat/long coordinates in comparable form? Negative values?
- Date/Time – standard format should be used (MM-DD-YYYY). All in same time zone.
- Depth – filled out and in the same units?
- Sample Media/Type – water, groundwater, air, effluent, stormwater, process water

Add user-specified fields to interpret, standardize, and clean up existing fields:

- Waterbody types – interpret and simplify
- Analytes/taxonomy – consistent use of analyte and taxa names
- Analytical method/sample fraction – consider accuracy and comparability of methods
- Units – standardize units and convert values as appropriate

Censored Data – Data that are reported as not detected or below detection limit should be utilized but accounted for statistically. Several methods are available to interpret censored data depending on the analysis. At this stage, maintaining MDLs and PQLs is likely appropriate to provide later analysis flexibility.

Data Transformation

Calculate metrics or new parameters based on the data available. For example:

- Calculate parameter sums or products (e.g., TN as sum of nitrate+nitrite and TKN).
- Calculate TSI, M-IBI, F-IBI, other biological indices.

Outliers – Analyze the data for potential outliers and consider screening those data that are clearly outliers and may introduce bias or error into the data set.

Document the process to ensure quality assurance and reproducibility.

Attachment 2. Data Source Field-specific Water Quality Data Tips

Several fields that provide more information about the sampling process or sampling location are often included with water quality data. These fields might include sample media, sample type, sampling type or location, and waterbody type. These fields might need to be interpreted or transformed to select the data that are of interest to the analysis. Descriptions of common fields and transformations that should be considered include the following:

- **Sample media:** A field or two for sample media (e.g., water, soil, groundwater) are sometimes included. They can be used to verify that the correct query selections were made for the sample media of interest. Sometimes sample subdivisions identify distinctions that should not be included in an ambient analysis (e.g., effluent, process water).
- **Sample type:** A field is sometimes included that identifies routine samples versus duplicate or quality control samples (spike samples, field replicates, laboratory replicates, or other duplicates). Checking routine values against duplicate values can be a valuable quality control check, but also ensure that duplicate values are not included in the data set used for analysis.
- **Sampling type or location:** Fields indicating the type of sampling, such as effluent, ambient, stormwater, baseflow, pipes, finished water, or process water, are sometimes available. Consider the location of the sampling effort. Sampling focused on effluent outfalls or on pristine waters could introduce bias into an analysis, depending on what the purpose of the project is. Sampling type or location can be an important indicator of sampling bias or spatial bias inherent in the data set resulting from opportunistic sampling rather than random sampling.
- **Waterbody type:** An indication of the type of waterbody where the sampling occurred might be included (e.g., stream/river, lake/reservoir, estuary, ocean, wetland, canal, stormwater). This field can be used to further subset sampling data to the data of interest.

Descriptive fields such as temporal indicators (e.g., date, year, time), sample depth, latitude/longitude, or units are often included in varying formats. A description of common fields and transformations that should be considered is provided below:

- **Temporal:** Ensure all date and time fields are in the same format (e.g., MM-DD-YYYY, YYYY-MM-DD). It is recommended that you use military time and account for time zones. It might be helpful to have one field with "Date" and separate fields for "Year," "Month," "Day," and "Time." If a measurement of diurnal fluctuations is not needed in a parameter, averaging data by day might remove some inconsistencies resulting from data without time information or with slightly different times due to different processing labs or data entry error. Searching for dates outside the range of interest or outside reasonable date or time values (e.g., month <1 or >12, day <1 or >31, year <1900, time <0 or >24) can be a helpful screening tool. Having a sampling date is a reasonable minimum requirement for data.

- **Depth:** Depth should generally be a numeric field. Sometimes a surface or bottom indicator is included as well a numeric depth field (e.g., S, B). It can be helpful, especially in lakes and estuaries, to add a separate text depth column for profile data that indicate surface, depth, or bottom measurements for some parameters (e.g., dissolved oxygen). Depth units should be standardized to a consistent format (feet or meters).

- **Latitude/Longitude:** Ensure that latitude and longitude are reported in a consistent format. Latitude and longitude units are most often reported in degrees, minutes, and seconds (DMS) (e.g., 39°59'56.055"N, 102°3'5.452"W), decimal degrees (DD) (e.g., 39.999012, -102.052062), or sometimes Universal Transverse Mercator (UTM) coordinates (e.g., 13N 751705 4431801). The examples provided are all roughly from the same point on the border of Kansas, Nebraska, and Colorado. To convert from DMS to DD, use the formula: (degrees) + (minutes/60) + (seconds/3600) = decimal degrees. If values are missing, consider digitizing from GIS or geocoding from an address if provided. One of the most frequent errors is omitting the negative sign (-) in decimal degree coordinates from the southern or eastern hemispheres. If all the records are from North America, all the longitude values should include a negative sign. Consider spatial accuracy. With today's standards, be wary of decimal degree data with less than six digits of precision accuracy or seconds reported with less than two digits of precision (although for larger waterbodies less precision might be acceptable). A typical minimum data requirement for station-level data is that the station must have a latitude and longitude measurement as well as the reported datum. Look for extreme values: Latitude should never be outside the range of 90 to -90 degrees; longtiude, 180 to -180.
- **Units:** Standardize units by parameter and among parameters. Check for systematic incorrect reporting of units when converting all values for a parameter to one unit of measurement. Note that laboratories often report results on a weight-per-weight basis, such as parts per million (ppm) or part per billion (ppb). In water samples, 1 ppm is essentially equivalent to 1 mg/L and 1 ppb is equivalent to 1 µg/L unless concentrations are very high (>7,000 mg/L) (Edwards 1986). In addition, µg/L and mg/m^3 can be considered identical in most cases in water samples. Outliers for a parameter might be an indication that data are reported in varying units.

Appendix C. Tetra Tech SOP for Geospatial and Data Management

Geospat al and Data Management

Approved by: Name: Susan Lanberg Title: QA Officer

Signature: Date:

Scope and Applicability: This procedure is designed for analysts and project managers to have quality assurance/quality control *(QNQC)* information readily available during project start up to aid in developing quality assurance project plans (QAPPs), as well as in closing out projects and in documenting QC tasks. Specific procedures are project-specific and require the input of analysts and project managers to determine the best course of QC measures to apply. In most cases, all of the information and procedures described in this document will not apply to each project, but rather project managers can pick and choose which apply to their project. The information described in this document is designed to provide general *QNQC* background material related to geospatial and data management tasks.

Responsibility and Personnel Qualifications: The Tetra Tech Project Manager, Geographic Information System (GIS) Manager, QA Officer, and QC Officer should refer to this procedure to ensure that *QN QC* requirements set by the client are met. The Tetra Tech Project Manager supervises the overall project and is responsible for coordinating project assignments; establishing priorities and schedules; ens uring com pletion of high-quality projects within established budgets and schedules ; providing guidance, technical advice, and evaluating the performance of those assigned to the project; implementing corrective actions; preparing or overseeing preparation and review of project deliverables; and providing support to the client in interacting with the project team, technical reviewers, and others to ensure that technical quality requirements are met in accordance with the client's objectives. The Tetra Tech Project Manager will have the primary day-to-day contact with the client Project Manager. This approach allows the client to work directly with the person conducting or supervising the project. The Tetra Tech

GIS Manager will supervise the geospatial information operations performed for the project and the Tetra Tech QC Officer is responsible for checking those activities. A QC Officer is a technical staff member who is familiar with the project tasks but does not participate in the task or subtask that he or she checks. The Tetra Tech QA Officer, with the assistance of the assigned QC Officer, will monitor QC activities to determine conformance with project QA/QC requirements.

Procedures

1. Project Setup Procedures: The Tetra Tech Project Manager will circulate copies of the client statement of work to the project team, including the QA Officer and key personnel, for their input on staffing, QA requirements, and logistical issues identified in the statement of work.

2. Data Check-In:

   a. *Input Data Integrity*: Data are spot-checked to detect potential data entry errors. In addition, Tetra Tech may use a customized user input interface that performs certain appropriate checks on data as they are being manually entered when a project involves the input of large quantities of data, thereby reducing the potential for incorrect data entry. In any project with automated processing it is important to visually inspect the GIS data to check for adherence to database design, attribute accuracy, logical consistency and referential integrity.

   b. *Assessments of Processed Data*: The ability of a desktop geospatial product to accurately characterize the conditions in the project area are dependent on the quality of data entering the process and imported into a GIS. QC procedures are implemented during data processing activities, and technical reviews of processed data are conducted by qualified personnel. Tetra Tech follows guidance on data management, information security, record management, and data processing provided or referenced by the client, including *Data Standards* (EPA CIO 2133.0), *Information Resources Management Policy Manual* (EPA CIO 2100.0), *Records Management Manual* (EPA CIO 2155.0), and *Records Management Policy* (EPA CIO 2155.1) available on the Internet at http://www.epa.gov/irmpoli8.

3. Automation Plan: Large data sets require automated processes to ensure efficiency and accuracy. Macros can be a way to automate multiple processes in sequence. When using a macro in a database-related software, the macro must be coded in a way that the result can be independently followed and replicated. In these cases it is important to be able to trace an error back to the step it was introduced.

   For GIS related processes, Earth Systems Research Institute's (ESRI's) ModelBuilder tool can help do the same task by linking multistep processes together and producing a visual flow diagram to track automated processing. In any project with automated processing it is important to visually inspect the GIS data to check for adherence to database design, attribute accuracy, logical consistency and referential integrity. Any visual inspection will be coupled with automated QA to ensure formulas and GIS algorithms have worked to their desired effect.

4. Data Organization: All information that is received by the project will be tracked and maintained from the moment of receipt, even though it may not be used in the final products for various reasons. Submitted and retrieved information, including suggested data sources and citations, will be immediately recorded to allow traceability throughout the entire lifecycle. Collected data will be stored via a directory structure that will allow Tetra Tech to work on and analyze copies of the data, while preserving the original versions. This will be accomplished by creating a 'RAW' and 'WORKING' directory structure that Tetra Tech has successfully used in the past.

   Throughout the actual GIS data processing, analysis, and layout, a GIS practitioner will generate many versions of a shapefile. This includes all the edits needed to suit the particular function of the project. The final shapefiles folder will contain the final version after edits of all the shapefiles, including those that were used to create map figures. A "Test_Shapefile" folder may house all the separate versions of shapefiles. This includes all the spatial joins, clips, projections, or anything else that was not used in the final product. Additionally, a "Draft_Shapefile" folder may house edited versions that needed to be updated with more current data and shapefiles that were used for a portion of the project but not the final output.

5. Product Review: Tetra Tech will document the data collected in the final report of each project, as well as, a description of all QC activities and analyses where data analysis assumptions or procedures were not obvious. Summary statistics and discussion will include the following:

   - Quality of secondary data (requirements will be determined in consultation with the client).
   - Accuracy of extraction/interpretation of pertinent data from secondary data sources for use in deliverables.
   - 10 percent of extractions/interpretations will be checked (100 percent of discrepancies will be resolved).
   - Accuracy of data transfers will be checked. The Tetra Tech QC Officer will independently check transferred data using a standard-level review, consisting of independently checking each different file type (i.e., a file with different structure or legacy), and confirming that the first, last, and a selected middle portion of the data were transferred correctly. More files (up to 10 percent) will be reviewed if files are processed individually, while fewer checks (no less than 2 data files of each type) will be used for automated to semi-automated procedures. All identified data processing errors will be corrected and the Tetra Tech QC Officer will perform a follow-up review of the correct components to ensure that the errors have been corrected.

- Hand-entered data will be checked (100 percent of discrepancies will be resolved).
- Accuracy of data conversions, including reformatting, will be checked. The Tetra Tech QC Officer or his or her designee will perform up to 10 percent independent recalculations of computations (including conversions) and graphs, but no less than two examples of each type of computation and two examples of each graphic type. More calculations (up to 10 percent) will be reviewed if data sets or points are processed individually while fewer checks (no less than two examples of each type of computation and two examples of each graphic type) are appropriate for automated to semi-automated procedures. All identified data calculation errors will be corrected and the Tetra Tech QC Officer or his designee will perform a follow-up review of the corrected components to ensure that the errors have been corrected.

6. Data Management: Most work that Tetra Tech conducts involves acquiring and processing data, and generating reports and documents, all of which require the maintenance of computer resources. Tetra Tech's computers are either covered by on-site service agreements or serviced by in-house specialists. When a problem with a microcomputer occurs, in-house computer specialists diagnose the trouble and correct it if possible.

   When outside assistance is necessary, the computer specialists will call the appropriate vendor. For other computer equipment requiring outside repair and not covered by a service contract, local computer service companies are used on a time-and-materials basis. Routine maintenance of microcomputers is performed by in-house computer specialists. Electric power to each microcomputer flows through a surge suppressor to protect electronic components from potentially damaging voltage spikes. Employees who keep important data on their personal desktop or laptop computers are given backup drives. These drives are set to conduct automatic backups of key data. Employees also receive instructions on how to manually back up key files. Tetra Tech's network servers are backed up daily. Copies of the backed-up data are kept off-site. On request or as needed, Tetra Tech archives and documents data for easy restoration. Automated screening systems have been placed on all Tetra Tech systems and are updated regularly to ensure that viruses are identified and destroyed. Annual maintenance of software is performed to keep up with evolutionary changes in computer storage, media, and programs.

7. Data Transfer/Transmittal: Data that are transferred among databases will be checked for completeness at the time of transfer by enumerating the numbers of records in the original and final data sets. Data transfers will be tagged with upload dates and times to accommodate completeness reviews. If data transfer is incomplete, the missing records will be sought and transferred individually if they are valid. A second round of completeness checks will ensue after successive transfers. Once data sets are compiled, the complete set of data value distributions will be analyzed to identify outliers that may result from data entry errors or erroneous unit conversions. Outliers will be identified and

resolved. Valid outliers can occur and will not be eliminated if the experienced analyst thinks they are plausible. Outliers that are not plausible or show a pattern of potential error will be brought to the attention of the original data supplier (if possible) and will be excluded from analysis until the original data supplier can confirm their validity.

The accuracy of the transfer of data from electronic databases to the project database(s) will be determined by checking whether data from the original database have been transferred to appropriate rows and columns, whether the same number of decimal places after the decimal point in the original database has been used, and whether the same units from the original database have been used. The Tetra Tech QC Officer will independently check transferred data using a standard-level review, consisting of independently checking each different file type (i.e., a file with different structure or legacy), confirming the first, last, and a selected middle portion of the data were transferred correctly. More files (up to 10 percent) will be reviewed if files are processed individually while fewer checks (no less than two data files of each type) will be used for automated to semi- automated procedures. This procedure will aid the evaluation process by improving consistency in data transfers.

Spatial data such as shapefiles and model input files are often composed of a family of files that need to be stored together to function. When transferring spatial data, consider that all of these files should be transferred together and that project files such as .mxds will need to be relinked after the files have been moved. Geodatabases are also available, and they are becoming more common for storing multiple spatial data sets for a project while maintaining data set relationships, behaviors, annotations, and metadata.

Data generated within a GIS platform will likely be too large to deliver over email. In these cases setting up an FTP site may be necessary. Ensuring the file size that is in the product posted to the FTP size is the same size as the project downloaded by the end user is a good way to ensure all data has been successfully transmitted.

8. Data Projections: All spatial data should have the same coordinate system for comparison; therefore, transformations are often necessary. Coordinate systems include both a geodetic datum and a projection type. A geodetic datum describes the model that was used to match the location of features on the earth's surface to coordinates on the map. Common datums include the World Geodetic System 1984 (WGS84) for a good representation for the world as a whole and the North American Datum 1983 (NAD83) or 1927 (NAD27) for a representation for North America. A projection type (e.g., the Universal Transverse Mercator [UTM] or state plane) is a visual representation of the earth's curved surface on a flat computer screen or paper. Often, if available, a state plane coordinate system or other state system is the most accurate system for a particular project area. Spatial data sets can be in the same projection but be referenced to different datums and therefore have different coordinate values (e.g., latitude and longitude or UTM). To fully represent a location spatially and avoid errors or confusion, coordinates are needed along with the datum. The difference between WGS84 and NAD83 is basically negligible (about 1 meter); however, the difference between NAD27 and

NAD83 (and WGS 1984) varies from about 10 meters in the Great Lakes area to 100 meters on the west coast and up to 400 meters in Hawaii. NAD27 is still used as the basis for most USGS topographic maps, but NAD83 was created to provide a more accurate representation of the earth's ellipsoid shape. By default, most GPS units export points in WGS84, but settings can be changed to display points using different systems. Significant error can be introduced when data with different or unknown datums are introduced, including errors in distance or area measurement and errors in relating the spatial location of features between data sets. GIS software or mathematical algorithms allow for the conversion of spatial data from one coordinate system to another.

9. Storage and Archives: Data storage involves keeping the data in such a way that they are not degraded or compromised and that any datum desired can be retrieved. At every stage of data processing at which a permanent collection of data is stored, a separate copy is maintained for purposes of integrity and security. Data are securely archived in a suitable manner. Aspects such as storage media, conditions, location, access by authorized personnel, and retention time are addressed in consultation with the client. Before archiving, the Tetra Tech Project Manager ensures that all data sets are complete, with all of the client-required data standards honored.

   Tetra Tech will store all computer files associated with the project in a project subdirectory (subject to regular system backups). Tetra Tech will maintain version control of draft and final deliverables by indicating the preparation date or revision number in the file name. The length of archival will be decided upon consultation with Client specifications.

10. Training Requirements: Project statements of work or work plans and quality assurance documents will be distributed to all project participants for review and reference. All relevant project personnel will have expertise in collecting and evaluating and analyzing GIS data. In addition, all relevant project personnel will have working knowledge of any additional software necessary to complete the project requirements.

    GIS Analysts should have access to ArcGIS software no earlier than version 10.0 for file compatibility purposes. All project personnel will have expertise in environmental sciences, as well as knowledge of the quality system for the project and this knowledge and expertise will be enumerated in project documentation.

Pertinent QA and QC Procedures

1. Spatial Data QA/QC: There are many considerations for spatial data QA/QC that must be adapted for each geospatial project. These considerations include the following, which were adapted from the ESRI GIS software developer:
   - GIS data completeness, consistency, accuracy, and resolution (including projection).
   - Identifying errors visually in ArcMap.

- Creating methods (data workflow) for project processes, including QC workflow for associated processes.
- Noting and tracking data errors either within attribute table fields or in associated project documentation.
- Checking schema (names, fields, and coordinate systems); checking attributes (missing or bad values).
- Visual review techniques: performing visual QC; setting symbols and labels; and labeling techniques for points, lines, and polygons.

The Tetra Tech Project Manager will determine in consultation with the client Project Manager how spatial data QA/QC will be implemented for a particular project.

2. Attribute Data QA/QC: All geospatial data (shapefiles) downloaded from publicly available online data sources will have associated attribute data contained within their respective database files. These attribute data quantify and occasionally narratively describe the spatial data within tabular fields. These data should be evaluated under the same measurement performance criteria that traditional data sources (spreadsheets and databases) are evaluated.

   Measurement performance criteria that will be used for data handling for any given project will include accuracy and completeness. Tetra Tech will also evaluate GIS metadata against the Federal Geographic Data Committee (FGDC) metadata standard to determine whether the GIS data are suitable for use for a given project. Tetra Tech will provide a description of the data evaluation factors and limits (as determined in consultation with the client) in the report of data collected. Whenever possible, data will be downloaded electronically from various electronic sources to reduce scanning of hard copy data.

3. Metadata QA/QC: Many projects will rely on secondary data. Geospatial metadata is used throughout the project lifecycle. All personnel that download geospatial secondary data become Metadata Stewards.

   Tetra Tech Metadata Stewards will evaluate GIS metadata against the FGDC (www.fgdc.gov) metadata standard to determine whether the GIS data are suitable for use for any given project. The FGDC has developed a metadata standard for geospatial data generated for and by all federal agencies which all federal agencies are to follow according to Executive Order 12906, *Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure*. Detailed metadata indicating the source, scale, resolution, accuracy, and completeness provide a basis to assess the adequacy of existing data for use per EPA Order 5360.1 A2, *Policy and Program Requirements for the Mandatory Agency-wide Quality System*.

If requested by the client through written technical direction, additional GIS QA/QC requirements can be addressed; examples include:

a. Full FGDC compliant metadata in XML format.
    i. Use the appropriate metadata profile described in the FGDC Content Standard for Digital Geospatial Metadata (CSDGM), such as Biological Profile, Shoreline Profile, and Remote Sensing Profile. Metadata profiles can be obtained from http://www.fgdc.gov/metadata.
b. A single file represents the entire data set (layer).
c. Each field that is mandatory and/or applicable must be described in the metadata.
d. The EPA Metadata Editor (EME) is used to create metadata (https://edg.epa.gov/EME/) and export to XML if using ESRI software.
e. Secondary data is accompanied by a metadata validation file. If a metadata validation file does not exist, metadata validation is performed prior to including the data set in the project. This is to ensure and document that the data set meets the needs of the intended use.
f. Where possible, extramural organizations are encouraged to use the EME. This facilitates subsequent review, collation, and verification of metadata validation.
g. The appropriate Geospatial Accuracy Tier noted in Appendix A of the EPA National Geospatial Data Policy is included as Supplemental Information. This facilitates collation of data and information related to scale.
h. Where practical, transition to the ISO 19115 metadata standards (North American Profile) is encouraged. At this moment, ISO metadata is optional.

4. Version Control: Data can be managed in a number of different platforms. GIS versioning can be managed through ESRI's ArcCatalog via folder and file naming conventions. Date of creation, ArcMap processing tool, and project name should all be reflected in the file name. Including spaces and non-traditional characters in file names is required for GIS processing and management.

Appendix D. National Risk Management Research Laboratory (NRMRL) QAPP Requirements for Research Model Development and Application Projects (10/2008)[1]

General Requirements: Include cover page, distribution list, approvals, and page numbers.

1. COVER PAGE (MODEL DEVELOPMENT AND MODEL APPLICATION)

   Include the Division/Branch, project title, revision number, EPA technical lead, QA category, organization responsible for QAPP preparation, and date.

2. PROJECT DESCRIPTION AND OBJECTIVES (MODEL DEVELOPMENT AND MODEL APPLICATION)

   In this document, "project" can mean (a) development or substantial modification of a model for application to address a general problem; (b) application of an existing model (including minor modification to the existing model) to address a specific problem; or (c) a development or substantial modification and application of a model to address a specific problem.

   2.1. State the purpose of the project and list the project objective(s). Indicate whether a new model will be developed, or an existing model will be used.

   2.2. Describe the problem, the data to be generated by the model, how the data will be used to address the problem, and the intended users of the data. Describe the environmental system/setting to be modeled, where the model will be applied, and the circumstances and scenarios to be considered for the modeled system.

3. ORGANIZATION AND RESPONSIBILITIES (MODEL DEVELOPMENT AND MODEL APPLICATION)

   3.1. Identify all project personnel, including QA, and related responsibilities for each participating organization, as well as their relationship to other project participants.

   3.2. Include a project schedule that includes key milestones.

4. MODEL SELECTION (MODEL APPLICATION ONLY)

   4.1. Discuss model selection with respect to how it will be used and how it is consistent with the project objectives. Include fundamental details such as whether the model will be used to predict the world beyond the model or in scenario analysis of the model itself. Describe the limits to where the model is applicable.

   4.2. Provide a description of the model attributes/capabilities required for the project. This description should include hardware requirements and restrictions. Provide an overview of the candidate model attributes.

      Model origin and its original purpose, if applicable

      Model structure (e.g., stochastic vs. deterministic, structural framework)

      Parameters and variables

[1] http://www.epa.gov/nrmrl/qa/pdf/ResearchModelDevandAppQAPPNRMRLrev0.pdf

The algorithms and equations that have been developed to support the model theory, along with the sources of the algorithms

Spatial extent (individual, group, population)

Spatial resolution (location independent/dependent, dimensionality)

Temporal extent (length of modeling period)

Temporal resolution (time step)

4.3. Identify the model to be used or, if the model has not yet been selected, describe the process to be used or the selection of an existing model.

4.4. Identify specific requirements for application of the selected model for this specific purpose (e.g., current and appropriate data, parameter values, assumptions).

4. MODEL DESIGN (MODEL DEVELOPMENT ONLY)

4.1. Describe the conceptual model(s) for the system, including model parameters.

4.2. Identify algorithms and equations that have been developed to support the model theory, or if such equations are not already available, describe the process used to develop these equations.

4.3. Specify required sources for model databases and any requirements for these data (e.g., quality, quantity, spatial, and temporal applicability). If data sources are not currently known, describe the criteria used to identify sources. Describe how any data gaps will be filled.

5. MODEL CODING (MODEL DEVELOPMENT ONLY)

5.1. Discuss the requirements for model code development, where applicable.

5.2. Identify computer hardware and software requirements.

5.3. Discuss requirements for code verification.

6. MODEL CALIBRATION (MODEL DEVELOPMENT AND MODEL APPLICATION)

Calibration is the process of adjusting model parameters within physically defensible ranges until the resulting predictions give the best possible or desired degree of fit to the observed data. Calibration should be applied each time the model is modified.

6.1. Discuss how the model will be calibrated.

6.2. Identify the type and source of data (e.g., new data, existing data, professional judgment, expert opinion elicitation) that will be used to calibrate the model, including any requirements for the data (quality, quantity, and spatial and temporal applicability). If data sources are not currently known, describe the criteria used to identify sources.

6.3. Specify acceptance criteria which need to be met for the difference between predicted and observed data during model calibration, where applicable. The statistical methods (e.g., goodness-of-fit, regression analysis) or expert judgment to be used should also be discussed.

7. MODEL VERIFICATION (MODEL DEVELOPMENT AND MODEL APPLICATION)

Verification consists of comparing the predictions of a calibrated model with available data that were not used in the model development and calibration.

7.1. Discuss the approach to be used for model verification. Describe how the verification is appropriate based on the model's purpose. Identify the type and source of data (e.g., new data, existing data, synthetic test data sets, professional judgment, expert opinion elicitation) that will be used to verify the model. If data sources are not currently known, describe the criteria used to identify sources.

7.2. Discuss the characterization of model uncertainty (model framework, model input, and model applicability) and sensitivity (model application only).

7.3. Describe any requirements (quality, quantity, and spatial and temporal applicability) for the data that will be used to verify the model.

7.4. Describe the approach used to determine if the independent data verify the model predictions. Specify the criteria which need to be met for the difference between predicted and observed data for the model to be considered to be verified. Discuss any statistical methods to be used (e.g., goodness-of-fit, regression analysis).

8. MODEL EVALUATION (MODEL DEVELOPMENT AND MODEL APPLICATION)

8.1. List and describe the qualitative or quantitative assessment process to be used to generate information to determine whether a model and its analytical results are of a quality sufficient for the intended use.

8.2. List and describe any independent/external evaluation and review of the model and model design, such as scientific peer review.

9. MODEL DOCUMENTATION (MODEL DEVELOPMENT AND MODEL APPLICATION)

Specify the requirements for model documentation. Good documentation includes:

Final model description, final model specifications (model development only), hardware and software requirements, including programming language, model portability, memory requirements, required hardware/software for application, data standards for information storage and retrieval

The equations on which the model is based (model development only)

The underlying assumptions

Flow charts (model development only)

Description of routines (model development only)

Data base description

Source code (model development only)

Error messages (model development only)

Parameter values and sources

Restrictions on model application, including assumptions, parameter values and sources, boundary and initial conditions, validation/calibration of the model, output and interpretation of model runs (model development only)

The boundary conditions used in the model

Limiting conditions on model applications, detail where the model is or is not suited

Changes and verification of changes made in code

Actual input data (type and format) used

Overview of the immediate (non-manipulated or –post processed) results of the model runs (model application only)

Output of model runs and interpretation

User's guide (electronic or paper)

Instructions for preparing data files (model development only)

Example problems complete with input and output

Programmer's instructions

Computer operator's instructions

A report of the model calibration, validation, and evaluation (model development only)

Documentation of significant changes to the model

Procedures for maintenance and user support, if applicable

10. REPORTING (MODEL DEVELOPMENT AND MODEL APPLICATION)
11. List and describe the deliverables expected from each project participant.
12. Specify the expected final product(s) that will be prepared for the project (e.g., journal article, final report).
13. REFERENCES

Provide the references either in the body of the text as footnotes or in a separate section.

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT		1. CONTRACT ID CODE		PAGE OF PAGES 1 2
2. AMENDMENT/MODIFICATION NO. P00002	3. EFFECTIVE DATE See Block 16C	4. REQUISITION/PURCHASE REQ. NO.		5. PROJECT NO. *(If applicable)*
6. ISSUED BY CODE CAD		7. ADMINISTERED BY *(If other than Item 6)* CODE		

CAD
US Environmental Protection Agency
26 West Martin Luther King Drive
Mail Code: W136
Cincinnati OH 45268-0001

8. NAME AND ADDRESS OF CONTRACTOR *(No., street, county, State and ZIP Code)*

TETRA TECH, INC.
Attn: John Hochheimer
10306 EATON PL STE 340
FAIRFAX VA 22030

(x)	9A. AMENDMENT OF SOLICITATION NO.
	9B. DATED *(SEE ITEM 11)*
x	10A. MODIFICATION OF CONTRACT/ORDER NO. EP-C-17-031 68HERC20F0051
	10B. DATED *(SEE ITEM 13)* 11/14/2019

CODE 198549560 FACILITY CODE

11. THIS ITEM ONLY APPLIES TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in Item 14. The hour and date specified for receipt of Offers ☐ is extended. ☐ is not extended.
Offers must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation or as amended , by one of the following methods: (a) By completing Items 8 and 15, and returning ________ copies of the amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted ; or (c) By separate letter or electronic communication which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGEMENT TO BE RECEIVED AT THE PLACE DESIGNATED FOR THE RECEIPT OF OFFERS PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If by virtue of this amendment you desire to change an offer already submitted , such change may be made by letter or electronic communication, provided each letter or electronic communication makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

12. ACCOUNTING AND APPROPRIATION DATA *(If required)*
See Schedule

13. THIS ITEM ONLY APPLIES TO MODIFICATION OF CONTRACTS/ORDERS. IT MODIFIES THE CONTRACT/ORDER NO. AS DESCRIBED IN ITEM 14.

CHECK ONE	
	A. THIS CHANGE ORDER IS ISSUED PURSUANT TO: *(Specify authority)* THE CHANGES SET FORTH IN ITEM 14 ARE MADE IN THE CONTRACT ORDER NO. IN ITEM 10A.
X	B. THE ABOVE NUMBERED CONTRACT/ORDER IS MODIFIED TO REFLECT THE ADMINISTRATIVE CHANGES *(such as changes in paying office, appropriation data, etc.)* SET FORTH IN ITEM 14, PURSUANT TO THE AUTHORITY OF FAR 43.103(b).
	C. THIS SUPPLEMENTAL AGREEMENT IS ENTERED INTO PURSUANT TO AUTHORITY OF:
	D. OTHER *(Specify type of modification and authority)*

E. IMPORTANT: Contractor ☒ is not ☐ is required to sign this document and return ________ copies to the issuing office.

14. DESCRIPTION OF AMENDMENT/MODIFICATION *(Organized by UCF section headings, including solicitation/contract subject matter where feasible.)*
DUNS Number: 198549560
TOCOR: Susan Jackson Max Expire Date: 11/13/2020
The purpose of this modification is to incorporate the attached EPA blanket administrative modification signed by Raoul Scott on July 30, 2020. All other terms and conditions remain unchanged.

Continued ...

Except as provided herein, all terms and conditions of the document referenced in Item 9 A or 10A, as heretofore changed, remains unchanged and in full force and effect.

15A. NAME AND TITLE OF SIGNER *(Type or print)*		16A. NAME AND TITLE OF CONTRACTING OFFICER *(Type or print)* Andrea Dehne	
15B. CONTRACTOR/OFFEROR (Signature of person authorized to sign)	15C. DATE SIGNED	16B. UNITED STATES OF AMERICA ELECTRONIC SIGNATURE (Signature of Contracting Officer)	16C. DATE SIGNED 10/13/2020

Previous edition unusable

STANDARD FORM 30 (REV. 11/2016)
Prescribed by GSA FAR (48 CFR) 53.243

NAME OF OFFEROR OR CONTRACTOR
TETRA TECH, INC.

ITEM NO. (A)	SUPPLIES/SERVICES (B)	QUANTITY (C)	UNIT (D)	UNIT PRICE (E)	AMOUNT (F)
	Payment: RTP Finance Center US Environmental Protection Agency RTP-Finance Center (AA216-01) 109 TW Alexander Drive www2.epa.gov/financial/contracts Durham NC 27711 Period of Performance: 11/15/2019 to 11/13/2020 Delivery-Invoice Payment Schedule shall not exceed a frequency greater than once a month and 90% of the task order price. Acceptance for invoicing is based on deliverable approval by the TOCOR. For efficient processing IAW FAR clause 52.232-32, performance based payment invoicing amounts will not be submitted until the TOCOR provides deliverable approval. The TOCOR will notify Tetra Tech within 14 days of submission of a deliverable of EPAs intention to approve or disapprove. TOCOR: Susan Jackson/(202)566-1112/jackson.susank@epa.gov ALTOCOR: Janice Alers-Garcia/(202)566-0756/alers-garcia.janice@epa.gov				

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. CONTRACT ID CODE	PAGE OF PAGES

2. AMENDMENT/MODIFICATION NUMBER	3. EFFECTIVE DATE	4. REQUISITION/PURCHASE REQUISITION NUMBER	5. PROJECT NUMBER *(If applicable)*
	08/13/2020		

6. ISSUED BY CODE

Raoul D. Scott, Director
OMS/ARM/OAS/Policy, Training and Oversight Division
US Environmental Protection Agency, Mail Code 3802R
1200 Pennsylvania Avenue, NW
Washington, DC 20004

7. ADMINISTERED BY *(If other than Item 6)* CODE

8. NAME AND ADDRESS OF CONTRACTOR *(Number, street, county, State and ZIP Code)*

To All EPA Contractors

CODE FACILITY CODE

(X)

☐ 9A. AMENDMENT OF SOLICITATION NUMBER

9B. DATED *(SEE ITEM 11)*

☒ 10A. MODIFICATION OF CONTRACT/ORDER NUMBER

To all EPA Contracts and Orders

10B. DATED *(SEE ITEM 13)*

11. THIS ITEM ONLY APPLIES TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in Item 14. The hour and date specified for receipt of Offers ☐ is extended. ☐ is not extended.

Offers must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation or as amended, by one of the following methods: (a) By completing items 8 and 15, and returning ____________ copies of the amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or electronic communication which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGMENT TO BE RECEIVED AT THE PLACE DESIGNATED FOR THE RECEIPT OF OFFERS PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If by virtue of this amendment you desire to change an offer already submitted, such change may be made by letter or electronic communication, provided each letter or electronic communication makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

12. ACCOUNTING AND APPROPRIATION DATA *(If required)*

13. THIS ITEM APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS. IT MODIFIES THE CONTRACT/ORDER NUMBER AS DESCRIBED IN ITEM 14.

CHECK ONE	
☐	A. THIS CHANGE ORDER IS ISSUED PURSUANT TO: *(Specify authority)* THE CHANGES SET FORTH IN ITEM 14 ARE MADE IN THE CONTRACT ORDER NUMBER IN ITEM 10A.
☒	B. THE ABOVE NUMBERED CONTRACT/ORDER IS MODIFIED TO REFLECT THE ADMINISTRATIVE CHANGES *(such as changes in paying office, appropriation data, etc.)* SET FORTH IN ITEM 14, PURSUANT TO THE AUTHORITY OF FAR 43.103(b).
☐	C. THIS SUPPLEMENTAL AGREEMENT IS ENTERED INTO PURSUANT TO AUTHORITY OF:
☐	D. OTHER *(Specify type of modification and authority)*

E. IMPORTANT: Contractor ☒ is not ☐ is required to sign this document and return ________ copies to the issuing office.

14. DESCRIPTION OF AMENDMENT/MODIFICATION *(Organized by UCF section headings, including solicitation/contract subject matter where feasible.)*

This contract/order is being modified in accordance with the applicability instructions in interim FAR Case 2019-009, and FAR 4.2105, requiring contracting officers to include FAR clause 52.204-25, Prohibition on Contracting for Certain Telecommunications and Video Surveillance Services or Equipment.

See attached for the full text version of FAR 52.204-25. Contractor Acknowledgment of receipt required.

Except as provided herein, all terms and conditions of the document referenced in Item 9A or 10A, as heretofore changed, remains unchanged and in full force and effect.

15A. NAME AND TITLE OF SIGNER *(Type or print)*		16A. NAME AND TITLE OF CONTRACTING OFFICER *(Type or print)*	
		Raoul D. Scott, Director Policy, Training and Oversight Division	
15B. CONTRACTOR/OFFEROR	15C. DATE SIGNED	16B. UNITED STATES OF AMERICA	16C. DATE SIGNED
(Signature of person authorized to sign)		RAOUL SCOTT Digitally signed by RAOUL SCOTT Date: 2020.07.30 11:40:17 -04'00' *(Signature of Contracting Officer)*	

Previous edition unusable

STANDARD FORM 30 (REV. 11/2016)
Prescribed by GSA FAR (48 CFR) 53.243

52.204-25 Prohibition on Contracting for Certain Telecommunications and Video Surveillance Services or Equipment.

As prescribed in 4.2105(b) and in the applicability instructions in interim FAR Case 2019-009, insert the following clause:

Prohibition on Contracting for Certain Telecommunications and Video Surveillance Services or Equipment (Aug 2020)

(a) *Definitions.* As used in this clause—

Backhaul means intermediate links between the core network, or backbone network, and the small subnetworks at the edge of the network (e.g., connecting cell phones/towers to the core telephone network). Backhaul can be wireless (e.g., microwave) or wired (e.g., fiber optic, coaxial cable, Ethernet).

Covered foreign country means The People's Republic of China.

Covered telecommunications equipment or services means–

(1) Telecommunications equipment produced by Huawei Technologies Company or ZTE Corporation (or any subsidiary or affiliate of such entities);

(2) For the purpose of public safety, security of Government facilities, physical security surveillance of critical infrastructure, and other national security purposes, video surveillance and telecommunications equipment produced by Hytera Communications Corporation, Hangzhou Hikvision Digital Technology Company, or Dahua Technology Company (or any subsidiary or affiliate of such entities);

(3) Telecommunications or video surveillance services provided by such entities or using such equipment; or

(4) Telecommunications or video surveillance equipment or services produced or provided by an entity that the Secretary of Defense, in consultation with the Director of National Intelligence or the Director of the Federal Bureau of Investigation, reasonably believes to be an entity owned or controlled by, or otherwise connected to, the government of a covered foreign country.

Critical technology means–

(1) Defense articles or defense services included on the United States Munitions List set forth in the International Traffic in Arms Regulations under subchapter M of chapter I of title 22, Code of Federal Regulations;

(2) Items included on the Commerce Control List set forth in Supplement No. 1 to part 774 of the Export Administration Regulations under subchapter C of chapter VII of title 15, Code of Federal Regulations, and controlled-

(i) Pursuant to multilateral regimes, including for reasons relating to national security, chemical and biological weapons proliferation, nuclear nonproliferation, or missile technology; or

(ii) For reasons relating to regional stability or surreptitious listening;

(3) Specially designed and prepared nuclear equipment, parts and components, materials, software, and technology covered by part 810 of title 10, Code of Federal Regulations (relating to assistance to foreign atomic energy activities);

(4) Nuclear facilities, equipment, and material covered by part 110 of title 10, Code of Federal Regulations (relating to export and import of nuclear equipment and material);

(5) Select agents and toxins covered by part 331 of title 7, Code of Federal Regulations, part 121 of title 9 of such Code, or part 73 of title 42 of such Code; or

(6) Emerging and foundational technologies controlled pursuant to section 1758 of the Export Control Reform Act of 2018 (50 U.S.C. 4817).

Interconnection arrangements means arrangements governing the physical connection of two or more networks to allow the use of another's network to hand off traffic where it is ultimately delivered (e.g., connection of a customer of telephone provider A to a customer of telephone company B) or sharing data and other information resources.

Reasonable inquiry means an inquiry designed to uncover any information in the entity's possession about the identity of the producer or provider of covered telecommunications equipment or services used by the entity that excludes the need to include an internal or third-party audit.

Roaming means cellular communications services (e.g., voice, video, data) received from a visited network when unable to connect to the facilities of the home network either because signal coverage is too weak or because traffic is too high.

Substantial or essential component means any component necessary for the proper function or performance of a piece of equipment, system, or service.

(b) Prohibition. (1) Section 889(a)(1)(A) of the John S. McCain National Defense Authorization Act for Fiscal Year 2019 (Pub. L. 115-232) prohibits the head of an executive agency on or after August 13, 2019, from procuring or obtaining, or extending or renewing a contract to procure or obtain, any equipment, system, or service that uses covered telecommunications equipment or services as a substantial or essential component of any system, or as critical technology as part of any system. The Contractor is prohibited from providing to the Government any equipment, system, or service that uses covered telecommunications equipment or services as a substantial or essential component of any system, or as critical technology as part of any system, unless an exception at paragraph (c) of this clause applies or the covered telecommunication equipment or services are covered by a waiver described in FAR 4.2104.

(2) Section 889(a)(1)(B) of the John S. McCain National Defense Authorization Act for Fiscal Year 2019 (Pub. L. 115-232) prohibits the head of an executive agency on or after August 13, 2020, from entering into a contract, or extending or renewing a contract, with an entity that uses any equipment, system, or service that uses covered telecommunications equipment or services as a substantial or essential component of any system, or as critical technology as part of any system, unless an exception at paragraph (c) of this clause applies or the covered telecommunication equipment or services are covered by a waiver described in FAR 4.2104. This prohibition applies to the use of covered telecommunications equipment or services, regardless of whether that use is in performance of work under a Federal contract.

(c) *Exceptions.* This clause does not prohibit contractors from providing—

(1) A service that connects to the facilities of a third-party, such as backhaul, roaming, or interconnection arrangements; or

(2) Telecommunications equipment that cannot route or redirect user data traffic or permit visibility into any user data or packets that such equipment transmits or otherwise handles.

(d) Reporting requirement.

(1) In the event the Contractor identifies covered telecommunications equipment or services used as a substantial or essential component of any system, or as critical technology as part of any system, during contract performance, or the Contractor is notified of such by a subcontractor at any tier or by any other source, the Contractor shall report the information in paragraph (d)(2) of this clause to the Contracting Officer, unless elsewhere in this contract are established procedures for reporting the information; in the case of the Department of Defense, the Contractor shall report to the website at https://dibnet.dod.mil. For indefinite delivery contracts, the Contractor shall report to the Contracting Officer for the indefinite delivery contract and the Contracting Officer(s) for any affected order or, in the case of the Department of Defense, identify both the indefinite delivery contract and any affected orders in the report provided at https://dibnet.dod.mil.

(2) The Contractor shall report the following information pursuant to paragraph (d)(1) of this clause

(i) Within one business day from the date of such identification or notification: the contract number; the order number(s), if applicable; supplier name; supplier unique entity identifier (if known); supplier Commercial and Government Entity (CAGE) code (if known); brand; model number (original equipment manufacturer number, manufacturer part number, or wholesaler number); item description; and any readily available information about mitigation actions undertaken or recommended.

(ii) Within 10 business days of submitting the information in paragraph (d)(2)(i) of this clause: any further available information about mitigation actions undertaken or recommended. In addition, the Contractor shall describe the efforts it undertook to prevent use or submission of covered telecommunications equipment or services, and any additional efforts that will be incorporated to prevent future use or submission of covered telecommunications equipment or services.

(e) *Subcontracts*. The Contractor shall insert the substance of this clause, including this paragraph (e) and excluding paragraph (b)(2), in all subcontracts and other contractual instruments, including subcontracts for the acquisition of commercial items.

(End of clause)

AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. CONTRACT ID CODE

PAGE OF PAGES: 1 of 2

2. AMENDMENT/MODIFICATION NO.	3. EFFECTIVE DATE	4. REQUISITION/PURCHASE REQ. NO.	5. PROJECT NO. (If applicable)
P00003	See Block 16C	PR-OW-21-00175	

6. ISSUED BY CODE CAD

CAD
US Environmental Protection Agency
26 West Martin Luther King Drive
Mail Code: W136
Cincinnati OH 45268-0001

7. ADMINISTERED BY *(If other than Item 6)* CODE

8. NAME AND ADDRESS OF CONTRACTOR *(No., street, county, State and ZIP Code)*

TETRA TECH, INC.
Attn: John Hochheimer
10306 EATON PL STE 340
FAIRFAX VA 22030

CODE 198549560 FACILITY CODE

(x) 9A. AMENDMENT OF SOLICITATION NO.

9B. DATED *(SEE ITEM 11)*

x 10A. MODIFICATION OF CONTRACT/ORDER NO.
EP-C-17-031
68HERC20F0051

10B. DATED *(SEE ITEM 13)*
11/14/2019

11. THIS ITEM ONLY APPLIES TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in Item 14. The hour and date specified for receipt of Offers ☐ is extended. ☐ is not extended.
Offers must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation or as amended , by one of the following methods: (a) By completing Items 8 and 15, and returning ____________ copies of the amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted ; or (c) By separate letter or electronic communication which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGEMENT TO BE RECEIVED AT THE PLACE DESIGNATED FOR THE RECEIPT OF OFFERS PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If by virtue of this amendment you desire to change an offer already submitted , such change may be made by letter or electronic communication, provided each letter or electronic communication makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

12. ACCOUNTING AND APPROPRIATION DATA *(If required)*
See Schedule

13. THIS ITEM ONLY APPLIES TO MODIFICATION OF CONTRACTS/ORDERS. IT MODIFIES THE CONTRACT/ORDER NO. AS DESCRIBED IN ITEM 14.

CHECK ONE	
	A. THIS CHANGE ORDER IS ISSUED PURSUANT TO: *(Specify authority)* THE CHANGES SET FORTH IN ITEM 14 ARE MADE IN THE CONTRACT ORDER NO. IN ITEM 10A.
	B. THE ABOVE NUMBERED CONTRACT/ORDER IS MODIFIED TO REFLECT THE ADMINISTRATIVE CHANGES *(such as changes in paying office, appropriation data, etc.)* SET FORTH IN ITEM 14, PURSUANT TO THE AUTHORITY OF FAR 43.103(b).
	C. THIS SUPPLEMENTAL AGREEMENT IS ENTERED INTO PURSUANT TO AUTHORITY OF:
X	D. OTHER *(Specify type of modification and authority)* BILATERAL AGREEMENT - CONFIRM DELIVERABLE RECEIPT IN FULL FOR TASK ORDER CLOSEOUT

E. IMPORTANT: Contractor ☐ is not ☒ is required to sign this document and return 1 copies to the issuing office.

14. DESCRIPTION OF AMENDMENT/MODIFICATION *(Organized by UCF section headings, including solicitation/contract subject matter where feasible.)*

DUNS Number: 198549560
TOCOR: Susan Jackson Max Expire Date: 11/13/2020
LIST OF CHANGES:
Reason for Modification: Confirm Order Close Out

Continued ...

Except as provided herein, all terms and conditions of the document referenced in Item 9 A or 10A, as heretofore changed, remains unchanged and in full force and effect.

15A. NAME AND TITLE OF SIGNER *(Type or print)*		16A. NAME AND TITLE OF CONTRACTING OFFICER *(Type or print)*	
		Andrea Dehne	
15B. CONTRACTOR/OFFEROR	15C. DATE SIGNED	16B. UNITED STATES OF AMERICA	16C. DATE SIGNED
(Signature of person authorized to sign)		ELECTRONIC SIGNATURE (Signature of Contracting Officer)	03/17/2021

Previous edition unusable

STANDARD FORM 30 (REV. 11/2016)
Prescribed by GSA FAR (48 CFR) 53.243

NAME OF OFFEROR OR CONTRACTOR
TETRA TECH, INC.

ITEM NO. (A)	SUPPLIES/SERVICES (B)	QUANTITY (C)	UNIT (D)	UNIT PRICE (E)	AMOUNT (F)
	Payment: RTP Finance Center US Environmental Protection Agency RTP-Finance Center (AA216-01) 109 TW Alexander Drive www2.epa.gov/financial/contracts Durham NC 27711 Period of Performance: 11/15/2019 to 11/13/2020 Delivery-Invoice Payment Schedule shall not exceed a frequency greater than once a month and 90% of the task order price. Acceptance for invoicing is based on deliverable approval by the TOCOR. For efficient processing IAW FAR clause 52.232-32, performance based payment invoicing amounts will not be submitted until the TOCOR provides deliverable approval. The TOCOR will notify Tetra Tech within 14 days of submission of a deliverable of EPAs intention to approve or disapprove. TOCOR: Susan Jackson/(202)566-1112/jackson.susank@epa.gov ALTOCOR: Janice Alers-Garcia/(202)566-0756/alers-garcia.janice@epa.gov				